U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-297 038

Areawide Waste Treatment and Water Quality Management Planning. Appendix C-4. The 208 Macroinvertebrate Study Report - The Effects of Acid Mine Drainage on Mean Species Diversity in Six Southern Illinois Streams

Greater Egypt Regional Planning and Development Commission, Carbondale, IL

Prepared for

Environmental Protection Agency, Chicago, IL. Region V

Nov 78

Areawide Waste Treatment and Water Quality Management Planning

PB 297038

The 208 Macroinvertebrate Study Report – The Effects of Acid Mine Drainage on Mean Species Diversity in Six Southern Illinois Streams Appendix C-4

Franklin, Gallatin, Hamilton, Hardin, Jackson, Jefferson, Perry, Pope, Saline, and Williamson Counties, Illinois

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

Areawide Waste Treatment and Water Quality Management Planning

The 208 Macroinvertebrate Study Report – The Effects of Acid Mine Drainage on Mean Species Diversity in Six Southern Illinois Streams

Appendix C-4

Franklin, Gallatin, Hamilton, Hardin, Jackson, Jefferson, Perry, Pope, Saline, and Williamson Counties, Illinois

The preparation of this report was financed entirely with federal funds from the U.S. Environmental Protection Agency under grant number P005225-01 through a contract with the Greater Egypt Regional Planning and Development Commission. The contents do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. Publication No. GERPDC-78-496.

BIBLIOGRAPHIC DATA SHEET	1. Report No. GERPDC-78-496	2.	3. Recipient's Accession No. PB297038
4. Title and Subtitle Areawide Waste Treatment and Water Quality Management Planning The 208 Macroinvertebrate Study Report: The effects of Acid Mine Drainage on Mean Species Diversity in Six Southern Illinois Streams, Appendix C-4			5. Report Date November 1978 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Greater Egypt Regional Planning and Development Commission P.O. Box 3160 Carbondale, IL 62901			10. Project/Task/Work Unit No. 11. Contract/Grant No. P005225-01
12. Sponsoring Organization Name and Address U.S. Environmental Protection Agency Region V 230 South Dearborn Chicago, IL 60604			13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

16. Abstracts

The 208 Macroinvertebrate Study Report: The Effects of Acid Mine Drainage on Mean Species Diversity in Six Southern Illinois Streams is Appendix C-4 of the Areawide Waste Treatment and Water Quality Management Plan for Southern Illinois. The report was prepared under Section 208 of the Water Pollution Control Act, as amended. It addresses the effect of acid-mine drainage from both deep shaft and strip mine operations in Southern Illinois upon macroinvertebrates. Included are descriptions of field sampling and laboratory methodology as well as findings and conclusions.

17. Key Words and Document Analysis. 17a. Descriptors

Coal mining, mine waters, surface mining, underground mining, ecology, water pollution, biology.

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement National Technical Information Service U.S. Department of Commerce Springfield, VA 22152	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 75
	20. Security Class (This Page) UNCLASSIFIED	22. Price A04-A01

FORM NTIS-35 (REV. 3-72) THIS FORM MAY BE REPRODUCED USCOMM-DC 14952-P72

GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

608 east college st. / carbondale, illinois / area code 618 549-3306
mailing address: post office box 3160 / carbondale, illinois / 62901

November 1978

Michael P. Mauzy
Acting Director
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Dear Mr. Mauzy:

The Commission is pleased to transmit Appendix C-4, The 208 Macroinvertebrate Study Report: The Effects of Acid Mine Drainage on Mean Species Diversity in Six Southern Illinois Streams of the 208 Areawide Waste Treatment and Water Quality Management Plan for Southern Illinois. The plan and this document cover the ten Illinois Counties of Franklin, Gallatin, Hamilton, Hardin, Jackson, Jefferson, Perry, Pope, Saline, and Williamson.

This technical report is an integral part of the Southern Illinois Water Quality Management Plan that is designated to meet the contract requirements of Federal Grant Number P005225-01 under the U. S. Water Pollution Control Act Amendments of 1972, as administered by the United States Environmental Protection Agency.

We trust this submittal of this report, as well as the others comprising the plan, will provide the basis for certification of the plan and continued designation of this area.

Sincerely,

A. S. Kirkikis

A. S. Kirkikis
Executive Director

ASK:db

1a

GREATER EGYPT REGIONAL PLANNING AND DEVELOPMENT COMMISSION

Commission Members

Franklin County

R.A. Bonifield
Albert Chiaventone
Russell Davis
George Tomlinson

Jackson County

Osbin Ervin
Bill Kelley
Reginald Stearns
Sharon Kowalzik

Jefferson County

Charles Covington
Paul Dickerson
David Sargent
Carl Baker

Perry County

Dr. Allen Y. Baker
J. Paul McNutt
Gene Schumaier
Victor Provart

Williamson County

William Humphreys
Jo M. Walker
Curtis Palmer
Jack Murray

Assembly of Local Governments

Williams Schettler

Conservancy District

Charles Prather

Municipal Representatives

Herbert Mundell, Benton
Archie Jones, Carbondale
Robert Armstrong, DuQuoin
Robert Butler, Marion
Raymond Baril, Mt. Vernon
Joe Williams, Murphysboro
Jack Woolard, West Frankfort

Executive Committee

Chairman -	Jo M. Walker
1st Vice Chairman -	Reginald Stearns
2nd Vice Chairman -	Archie Jones
3rd Vice Chairman -	J. Paul McNutt
Secretary -	George Tomlinson
Treasurer -	William Humphreys
Immediate Past Chairman -	C.J. Covington

ACKNOWLEDGMENTS

The Greater Egypt Regional Planning and Development Commission and the Southeastern Illinois Regional Planning and Development Commission wishes to acknowledge the

United States Environmental Protection Agency

for financial assistance in the preparation of this report.

The Regional Commissions express their appreciation to the Illinois Environmental Protection Agency for their assistance and cooperation during the initial planning program.

The assistance of the Tri-County Health Department, Cairo, and the Quadri-County Health Department, Vienna in regard to editing for correct terminology, soils information, and other relevant information is especially appreciated. We also gratefully acknowledge the help of individuals at Perry County Health Department, Egyptian Health Department, and the Region 5 office of Illinois State Health Department for information regarding the nature and extent of private sewage treatment problems, present status of enforcement, workable educational approaches, and management needs.

In addition, the Regional Commissions would like to thank the members of the Technical and Policy Advisory Committees to the program; the Federal and State Agencies; and the many public officials and citizens too numerous to mention who have offered information and suggestions during the initial phase of the planning program.

Commission Staff

A. S. Kirkikis - Executive Director
James R. Rush - Director of Special Programs
Christine Svec - Director of Long Range Planning
Ronald Clark - Director of Current Planning
Wayne Martin - Criminal Justice Training Coordinator
Saeed Khan - Engineer
R. Jon Herbert - Planner II
Gary Bankston - Planner II
Joseph Wesselman - Planner I
Ronald Hudson - Planner I
William M. Harris - Planner I
Sharon Yeargin - Planner I
Tom Redmond - Planner I
Rue Gene Starr, Sr. - Manpower Specialist
Jack VanZandt - Evaluation Specialist II
Stephen Knox - Citizens Resource Specialist
Barbara Poston - Research Analyst II
James Dine - Research Analyst I
Nancy O'Connor - Research Analyst I
Margie Mitchell - Administrator II
Diana Chandler - Secretary III
Jean Sparenberg - Secretary II
Marleen Romero - Secretary II
Janet Kent - Planning Technician II
Bob Gerl - Planning Technician II
Wendell Keene - Planning Technician II
Janice Jones - Planning Technician II
Harold Dillard - Planning Technician II
Tom Wierzba - Intern

*Glenn Gill - Planner I - Former Staff

*Primarily responsible for this report.

SOUTHEASTERN ILLINOIS REGIONAL PLANNING AND DEVELOPMENT COMMISSION

Commission Members

Gallatin County

William Lawler
Tom Harmon
Stanley Sisk
Delbert York

Hardin County

Donald Austin
Winfred Barnard
Dayton Pearce
Walter Bayne

Hamilton County

Ernest Hood
C. H. McGill
James Mick
Dwight Miller

Pope County

Herman Adkerson
Ralph Aly
Milton Baker
Victor English

Saline County

Harry Hines
Fred Lloyd
Ray Harbison
Art Debes

Executive Committee

Chairman - Ralph Aly
1st Vice Chairman - Fred Lloyd
2nd Vice Chairman - Inman Wheeler
Secretary - Winfred Barnard
Treasurer - William Lawler

Commission Staff

Eric Pflanz - Acting Executive Director
Lu Ann Walker - Economic Development Director
Bonita Stanley - Manpower Planner
Pam Peckler - Health Coordinator
Judy Clark - Administrative Assistant/Bookkeeper
Jackie Walker - Secretary
Verba Elam - Clerical Assistant

ABSTRACT

As part of the Greater Egypt Regional Planning and Development Commission - Southeastern Illinois Regional Planning and Development Commission 208 water quality monitoring program, six Southern Illinois streams were studied to determine effects of acid coal mine waste effluents on macroinvertebrates. Collections were made during spring and summer, 1977, at 15 stations located above and below mine waste runoff and at three other stations unaffected by mine drainage. Methods included handpicking, sieving of sediments, the kick method, and placement of artificial substrates.

One hundred seventy-three species were collected from 1 to 45 species per station. Specimens per man-hour of collection ranged from 1.3 to 116.7. Mean species diversity ranged from 0 - 4.67 and was higher in unaffected reaches of a given stream than in segments affected by mine waste. Some basins exhibited a higher over-all mean diversity than others, but all showed decreased mean species diversity with increased indications of mine waste input.

A chemical profile of each station was prepared using maximum, minimum, and average pH, sulfates, total dissolved solids, suspended solids, alkalinity, and total iron. Data for these profiles were available from a six-month monitoring of key stations in 1976 and a shorter rain-fall response monitoring program in 1977. Flow, pH, temperature, and dissolved oxygen data were taken during collection of macroinvertebrates.

Mean species diversities below 3.0 were considered indicative of degradation of the stream habitat. At some stations the life support ability of the stream was seriously threatened. Low mean species diversity was associated with average pH below 5.0, average acidity above 30 mg/l, average suspended solids above 400 mg/l, average sulfate between 1,000 and 1,400 mg/l, and total iron above 20 mg/l in the presence of low sulfates, or above 1 to 3 mg/l in the presence of high sulfates. Relatively high mean species diversity was found where high sulfates and total dissolved solids existed when the acid buffering qualities of the stream were high and total iron averaged below 2 mg/l.

Representatives of Pentaneura, Stemonema, and the isopod Asellus intermedius were intolerant of the chemical profile parameters beyond "threshold" levels. The larval chironomid, Chirnomus anthracinus, was numerous at two stations having high levels of mine waste input parameters including total iron above 20 mg/l. The hemipterans, Microvelia and Trichorixa, were also found at two of the most affected sites, but were regarded as possible chance inhabitants.

TABLE OF CONTENTS

	Page
ABSTRACT	i
PREFACE	1
INTRODUCTION	3
STATION DESCRIPTIONS	9
Eagle Creek	9
Bankston Fork	10
Brushy Fork	11
Little Crab Orchard Creek	11
Sycamore Creek	12
Panther Creek	13
Comparator Stations	14
FIELD METHODS	17
LABORATORY METHODS	21
SPECIES DIVERSITY CALCULATION	23
RESULTS AND DISCUSSION	25
Physical Parameters	25
Specimen Yield	25
Intolerant and Tolerant Species	25
Mean Species Diversity	35
Chemical Parameters and Species Diversity	37
pH	37
Alkalinity	37
Sulfate	39
Total Iron	39
Species Diversity as an Indicator	39
Acid Mine-Waste Treatment	42
Conclusions	42
LITERATURE CITED	45
APPENDIX I - Micro-Cell Maps	47
APPENDIX II - Chemical Profiles of Stations	55
APPENDIX III - Linear Chart of Species Collected	59

LIST OF FIGURES AND TABLES

Page

Figure 1 - Generalized Life Cycle of the Mayfly 4

Figure 2 - An Artificial Substrate (exploded view) 20

Table 1 - Physical Characteristics of Water at Collecting Stations 26

Table 2 - Specimen Numbers Per Man-Hours Collection Time . . . 27

Table 3 - Distribution of Taxa Showing Low Tolerance to Mine Waste Drainage 29

Table 4 - Averages of Mine Waste-Related Parameters at Stations Inhabited and Not Inhabited by Three Mine Waste Intolerant Species 34

Table 5 - Mean Species Diversity at Micro-Cell and Comparator Stations 36

Table 6 - Average Mean Species Diversity at Stations Surpassing Threshold Values of Four Mine Related Parameters 38

Table 7 - Comparison of Mean Species Diversity, Average Total Iron and Average Sulfate 40

Plate 1 31

Figure 1 - Asellus intermedius
Figure 2 - Stenonema sp.
Figure 3 - Pentaneura sp.

Plate 2 33

Figure 1 - Trichocorixa sp.
Figure 2 - Chironomus anthracinus
Figure 3 - Mandible of C. anthracinus

PREFACE

This study has been designed to contribute biological considerations to the Greater Egypt Regional Planning and Development Commission - Southeastern Illinois Regional Planning and Development Commission 208 water quality management planning effort. It is intended to contribute in part to item A-1 under the Data Reduction section and to add biological parameters to item B-2-a (Mine Waste Programs) under the Water Quality and Base Data Acquisition section of the 208 Area Waste Treatment and Water Quality Management Planning Application/Work Program.

The ultimate 208 goal includes a desire to "restore and maintain" the "biological integrity" of the nation's waters. This goal makes biological input in general, and species diversity information in particular, necessary to a complete water quality evaluation.

The mission of this study is to insert basic biological data into the 208 micro-cell data gathering project and to demonstrate the usefulness of biological parameters in addressing problems of water quality assessment.

INTRODUCTION

Aquatic macroinvertebrates are animals large enough to be seen with the unaided eye and which live part of their life cycle within or upon available substrates in water (Weber, 1973). They are mostly immature and adult insects, crustaceans such as crayfish and water fleas, clams, snails, flatworms, and annelids. Sponges and bryozoans are also included.

Because macroinvertebrates are adapted to many kinds of stream habitats, many species are found in any undisturbed stream in Southern Illinois. They are found in the various niches of an aquatic community; many are food for game fishes we most like to see in fishing waters. Crayfish, Tubificid worms and immature insects are an important part of the diet of bass, bluegill, and other fish.

Insect species are the most common macroinvertebrates in streams of the 208 area. Most are aquatic at the larva or nymph stage of their life cycle. Because more are hatched than required to reproduce the population, great numbers of them are available for fish and other predators as food. Figure 1 shows the generalized life cycle of the Ephemeroptera (mayflies), a group of insect species commonly found in streams of the 208 area.

Diverse groups of species tend to form balanced communities of plant and detritus feeders, as well as carnivores and scavengers. A disturbance of the stream habitat tends to alter this balance and results in a reduction in the number of different species and an increased population of the species best able to tolerate changes that have occurred. The relative tolerance or intolerance of each species to pollution will determine which species can or cannot survive and reproduce. Herricks and Shanholtz (1976), who studied the effects of acid mine drainage on aquatic organisms, cited addition of toxic materials and increased loading of suspended solids as the principal factors which make streams unsuitable for habitation.

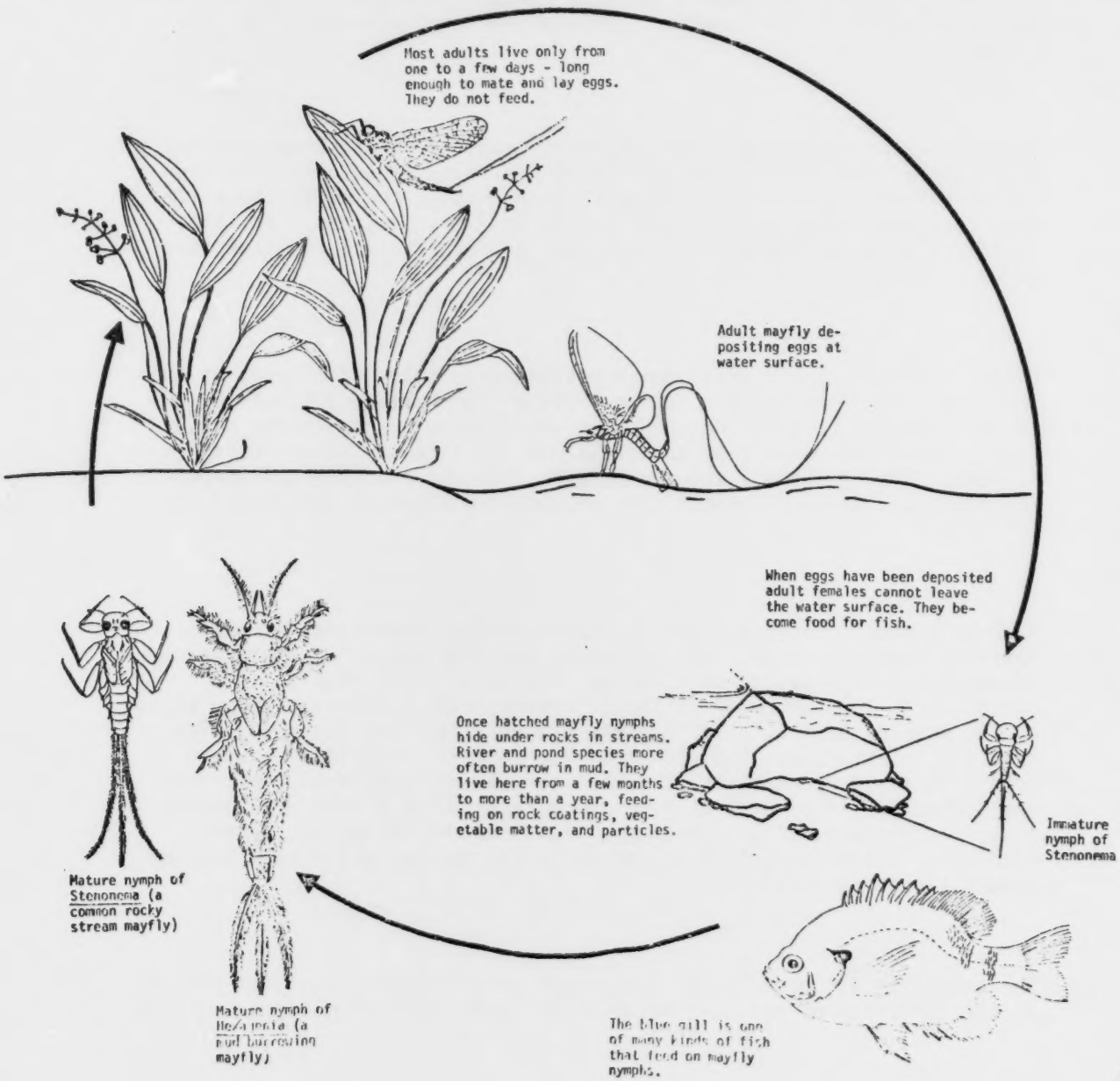
The oxidation and hydrolysis of iron and other metallic sulfides result in the formation of acid and metal salts. The resulting lowered pH plus

Preceding page blank

FIGURE 1

Generalized Life Cycle Of The Mayfly

(A Typical Aquatic Macroinvertebrate Group)


Most adults live only from one to a few days - long enough to mate and lay eggs. They do not feed.
Adult mayfly depositing eggs at water surface.
When eggs have been deposited adult females cannot leave the water surface. They become food for fish.
Once hatched mayfly nymphs hide under rocks in streams. River and pond species more often burrow in mud. They live here from a few months to more than a year, feeding on rock coatings, vegetable matter, and particles.
Immature nymph of Stenonema
Mature nymph of Stenonema (a common rocky stream mayfly)
Mature nymph of Hexagenia (a mud burrowing mayfly)
The blue gill is one of many kinds of fish that feed on mayfly nymphs.

the toxicity of heavy metal salts eliminate many species that would be expected in the streams. In unpolluted streams a pH neutrality is maintained by the natural bicarbonate-carbonic acid buffering system (Hynes, 1972). This system is destroyed when acid mine waste effluent enters the stream in great enough amount. The pH in such a stream falls as acidity rises because the basic buffering ions have been removed. Since some of the chemical reactions occurring in the stream are oxidizing reactions, a chemical oxygen demand is produced which can lower and even deplete the dissolved oxygen supply in the water. Sulfate levels, levels of iron and other metal salts and total dissolved solids increase in the affected stream. Downstream from the reaction zone of such a stream, a yellowish crust of precipitated iron hydroxide and other ferric compounds forms on the stream substrata. This coating of "yellow boy" makes most of the substratum surfaces uninhabitable by macroinvertebrates. Parsons (1968) and Rosso (1975) show that many species cannot survive the rigors of even the intermediate stages of these chemical reactions; however, the return of more nearly normal conditions will result in repopulation by macroinvertebrates. Hence, elimination, alteration, or significant reduction of acid mine waste input to streams can lead to re-establishment of a normal regional biota after sufficient time.

The effect of pollutants on the biota of an aquatic habitat can be measured using a species diversity index. The calculation of mean species diversity captures in one index number the mathematical relationship between the number of species and the relative number of individuals of each species present at a collecting station (Weber, 1973).

A balanced biotic community tends to have many species but relatively small numbers of each. This situation is enhanced if the habitat has a variety of substrata on which to attach or move or under which to seek protection, and further enchanced if aquatic plants are available. A decrease in number of species is symptomatic of degrading water quality. When one species numerically dominates the habitat, there is further evidence of habitat disturbance. A severe decrease in species diversity accompanied by redundancy in numbers of one species serves to indicate a severe habitat disturbance (Wihlm & Dorris, 1967), (Young, et al 1976).

The principal objective of this study was to determine to what extent biological symptoms of disturbance existed in the acid mine waste-affaffected stretches of six Southern Illinois streams. Additional objectives were:

1. To establish a biological information base from which future trend index monitoring can begin.

2. To define the expected normal aquatic macroinvertebrate fauna for the regions studied.
3. To discover examples of species that show tolerance or intolerance to mine waste pollution in Southern Illinois.
4. To obtain data that would in effect, add a biological parameter to the data already collected at selected 208 monitoring sites.
5. To demonstrate a method for determining the nature and level of known acid mine waste pollutants tolerated by a biotic community made up of species normally found in the 208 area in Southern Illinois.

By selecting stations from among the 208 micro-cell sampling sites, it was possible to examine macroinvertebrate populations in locations influenced by various levels of mine waste pollution. Collection of macroinvertebrate specimens began shortly after the micro-cell sampling data were gathered. Chemical data were available for all stations from the current year and for some stations for 1976 and 1977.

The rainfall-response sampling program conducted in the spring of 1977 provided chemical and flow data from sites within five small watersheds (micro-cells) at periods of relatively high flow and accelerated run-off. Sites were located near sources of mine waste drainage, as well as up and downstream from stretches of stream receiving such drainage. Land use was categorized and charted in these five watersheds and boundaries of the watershed checked. New mining, mined-out areas, underground mine sites, and gob and slurry locations were charted. As a result, the drainage areas contributing to the flow in the streams have been well characterized.

Sampling and flow data for 1976 were available for some collecting stations from a larger six-month sampling program conducted during the spring, summer, and fall of 1976 covering the Big Muddy and Saline river drainage basins. Hence, both low and high flow chemical data were available.

The watersheds sampled in the micro-cell study included Eagle Creek in Saline and Gallatin counties, Bankston and Brushy Forks in Williamson and Saline Counties, Little Crab Orchard Creek in Williamson County, Sycamore Creek in Jackson County and Panther Creek in Perry County (Appendix I). The chemical parameters evaluated in the micro-cell and

six-month studies were total iron, sulfate, total dissolved solids, suspended solids, total hardness, alkalinity, acidity, and pH.

Available in Appendix II is a summary of chemical and flow data for each 208 sampling site used for collecting macroinvertebrates.

The micro-cell streams were chosen because the background information on these streams and related mine waste drainage areas in the watersheds was fairly complete. Because of the small size of these streams, elaborate equipment was not necessary and fewer stations were required for collections above and below pollution source areas. These streams also afforded a cross section of stream types and flow characteristics in Southern Illinois. Conclusions from data on the micro-cell main streams should have implications for all segments of the Big Muddy or Saline river basins.

STATION DESCRIPTIONS

Much of the following information was taken from the 208 micro-cell land use survey. County maps and on-site observations by the author supplied station description information.

Eagle Creek

The Eagle Creek watershed totals more than 36,000 acres. At the time of the land use survey, over 1,000 acres of this had been strip-mined for coal and left ungraded. Of this acreage, 230 acres was barren of vegetation. Approximately 80 acres currently being surface mined was contributing runoff to Station 3 described below. Over 16,800 acres of this watershed was forested and about 10,100 acres was cropland.

At Station 1 (208 sampling site E6; T10S, R7E, S.E. corner of Section 27) the creek was small but not intermittent. Flow estimations ranged from 0.01 to 0.03 cfs and water velocity was less than 1 fps. Except during periods of heavy rainfall runoff, the stream flowed from a series of possibly spring- fed pools just upstream from this station. The bottom was sand and rock. Much wood and leaf litter occurred because of the forest environment. No mine run-off entered the stream above this station.

Station 2 (208 sampling site E-3 and ATE-05; T10S, R8E, Section 10) is approximately 10 stream miles down from station 1. Most of the inactive strip mine acreage in the basin was upstream of this station and included much exposed mine refuse. There was considerable silt in parts of the stream bed, but rocks and rooted aquatic vegetation were present. The stream was a series of ponds and at times there was no flow between ponded water even though water was flowing at stations 1 and 3. Silt, which collected in artificial substrates at this station, included black silt like that eroded from mine refuse piles.

At Station 3 (208 Sampling site E-1 and ATE-01; T10S, R8E, Section 13) Eagle Creek flows over an exposed sandstone outcrop between deeper segments. The water velocity was more than 1 fps and was much higher in

Preceding page blank

places where the water flows over a rock shelf beneath the Illinois Route 1 bridge. The variable flow velocities and water depths plus a variety of aquatic vegetation from matted growth on rocks to standing rooted plants made this a diverse habitat. New strip mining upstream from this station and less than a mile away was contributing noticeable increases in sediment. However, this was not reflected in the chemical profile (Appendix II) because the mining activity is a recent event. Some inactive mining was also above this station but not as much as above Station 2.

Bankston Fork

The Bankston Fork watershed includes over 34,000 acres, of which more than 9,500 acres reflected past or present mining activity. Most of this area was ungraded strip mine land. Over 850 acres of gob and slurry were exposed in the watershed. About 800 acres of water occupies old strip pits in the basin. Three collecting stations were located on Bankston Fork.

Station 4 (208 Sampling site B-13; T9S, R4E, at Route 13 bridge in Section 21) reflected a rapid flow from a ponded area containing rooted vegetation. The average flow was 2.81 cfs. Velocity in the riffle area was over 3 fps during intermediate flows. The stream bed was sandy at the pond outflow and rocky below that. All of the riffle substratum was coated with yellow boy and the water usually had a cloudy appearance. Both yellow and black sediments were collected in artificial substrates here.

Station 5 (208 Sampling site B-9; T9S, R4E, between Sections 13 and 24) was approximately 3 stream miles downstream from station 4. At this point the stream carries the additional water of one tributary and has passed through a series of ponded areas within reclaimed strip mine land. The tributary drains both reclaimed and active surface mine area. Flow varied between 3.81 and 1.25 cfs. Riffle velocities in excess of 3 fps were measured at this station. As at Station 4 water flows from a richly vegetated ponded area through a high velocity riffle area to a slow moving segment of stream. The rocks were not coated with yellow boy, but much black silt was found below the riffle area.

Station 6 (208 Sampling site B-5 and ATGC-02; T9S, R4E, at county road bridge in Section 11) showed a rapid flow over a sand and coal fines bottom in this channelized segment of Bankston Fork. Average flow was

4.6 cfs and water velocity approximately 1 fps. The stream bed was made up of sand which tends to drift and form bars. Some branches, logs, and leaf litter were present. The substratum contained chunks and chips of coal and mine refuse material. The sand was red in color and released a reddish silt when disturbed. Habitat variety was limited by high flow velocity, lack of rocky riffles, and lack of vegetation in the stream bed.

Brushy Fork

This stream has a 13,600-acre watershed. Over 200 acres were associated with past and present coal mining. Of this over 100 acres were gob and other mine refuse and over 30 acres occupied by mine-related water. Three collecting stations were chosen on Brushy Fork, but one was discarded due to its intermittent flow and long stretches of dry stream bed.

Station 7 (208 Sampling site B-2; T8S, R5E, S.E. corner of section 32) showed a small discharge except during rainfall run-off. Flow volume was calculated at 0.029 cfs on one collecting visit and was too interstitial to be measured on other visits. Riffle velocity was 0.5 fps. The stream flowed between ponded areas. In spite of its small flow, a variety of habitats were available. The bottom material was sand, clay, and rock. There was standing vegetation in the stream bed. Mine refuse, inactive strip mine area, an inactive underground mine, and coal outcrops are found upstream from this station.

Station 8 (208 Sampling site B-1 and ATGCS-10; T9S, R5E, between Sections 3 and 4) like Station 7, had little flow between rainfall events. Flow volume was 0.15 on one visit and was interstitial on other visits. Rocky riffles and ponded segments were present. The deeper ponds contained spawning fish in spring and early summer. Orange precipitate formed at specific spots among rocks, in the stream bed suggesting either a coal seam near the surface or the entrance of pyrite-polluted waters via aquifers. There was a variety of potential habitats at this station.

Little Crab Orchard Creek

The Little Crab Orchard watershed occupies 5,714 acres. Approximately 816 acres were or had been affected by mining activities; 126 acres of

refuse piles and preparation yard drain to Little Crab Orchard Creek along with about 129 acres of barren graded mine refuse. The stream was intermittent during the study period.

Station 9 (208 Sampling site C-3; T9S, R3E, Section 13) had flow only during wet seasons and as a result of heavy rainfall. The first collecting visit occurred at the end of the spring period of flow. At that time flow in the stream was 0.08 cfs. In late June, even the standing ponds were drying up, but the stream continued to flow after heavy rains due to water from the road ditches. Most of this water flowed from graded refuse from an inactive mine. Upstream the stream drains an old preparation area now used for coal storage as well as other mine-affected areas. The stream bed contained heavy black silt and a top layer of yellow boy. This precipitate also coated the rocks and logs in the stream. Nearby refuse pile grading and clearing for a power line may have increased silt and mine waste input at this station during the study period.

Station 10 (208 Sampling site C-1; T9S, R3E, near Route 166 bridge between Sections 14 and 15) had intermittent flow. The stream consisted of a series of small pools separated by damp sand. The sand at this station was red and contained a large quantity of coal fines. The pools had orange to greenish water and varied from each other in pH as much as 1.5. Grass and bushes grew in the stream bed, but trees were lacking and the stream was not shaded. Variety of habitat is not great at this station.

Sycamore Creek

Sycamore Creek has a watershed covering 3,627 acres. Several small mines extended into the basin occupying 238 acres of it. All mining was inactive. Some mine refuse in the area has been graded. A series of small tributaries carries run-off from acidic refuse into the stream in the lower part of this basin.

Station 11 (208 Sampling site S-3; T10S, R1W between Sections 1 and 12) was made up of a series of riffles through rocks alternating with wider slow flowing sections with sand bottom. It was well shaded and offered a variety of habitats. Flow averaged 0.09 cfs and riffle velocity was about 0.7 fps. All mining activity occurred downstream from this station.

Station 12 (208 Sampling site S-1 and NDJ-01; T9S, R1W, between Sections 25 and 26) had higher velocity as it flowed over sandstone and into a sandy stream bed about 150 ft. before joining Drury Creek. The flow volume averaged 0.155 cfs. Very high flows occurred here in heavy rainfall and copious amounts of ferric hydroxide laden silt have been deposited with the sand rendering it red in color. The sandstone was orange precipitate coated. There was no aquatic vegetation. All mining activity in the basin was upstream from this station.

Panther Creek

The Panther Creek watershed totals approximately 16,200 acres. Over 4,800 acres of the drainage basin had been disturbed by mining activities. This included 252 acres of gob, slurry, and preparation area. 602 additional acres were in strip pit ponds. Active surface mining occupied 345 acres of this watershed. Fully one third of this watershed had been or is being affected by surface mining for coal.

Station 13 (208 Sampling site P-4; T6S, R2W, east edge of Section 17) was located just downstream from an active surface mine. It received erosion deposits from graded and ungraded slopes in a portion of the mine area. The flow in this channelized segment of the stream was very small except in wet seasons and flash flood conditions. The stream bed had steep, eroding clay banks and silt deposits on the floor. There was no shade, so slow moving water became quite warm in summer. A stretch of faster flowing water ran over hard packed clay bottom material from the ponded water at the station. Algae and rooted vegetation occurred in the ponded segment and some of the riffle segment was shaded by grass, so the stream afforded some habitat diversity.

Station 14 (208 Sampling site P-2; T4S, R2W, at boundary of Sections 8 and 9 near juncture of Sections 8, 9, 4, and 5) was 600 feet down from a county road where Panther Creek flows out of a long ponded stretch. The stream was well shaded and received a rich supply of leaf litter and wood for potential food and substrata. On visits to this station, flow ranged from about 0.5 to about 0.2 cfs with a riffle velocity of about .5 fps. There were signs of periodic silt deposition, but silt deposits were well mixed with leaves, sticks and humus. There were no overt signs of coal mine acid waste discharge at this station.

Station 15 (208 Sampling site P-1 and NCP-04; T6S, R2W, east edge of

Section 17) was established about 300 feet upstream from Route 152 where Panther Creek divided into two fast flowing channels around a small log jam and silt island below a channelized slow flowing stretch. There was heavy black and orange silt deposition in the slower stretches -- such that it was difficult to walk in the stream. Water velocities up to 2.5 fps were found in the fast channels. The average flow volume was about 5 cfs. The water carried a silt load at all times. This station was well shaded and had a rich input of leaf litter and wood. There was potentially a good and varied habitat for macroinvertebrates.

Comparator Stations

These stations were chosen to exemplify conditions as they would be without mining input. They were similar in location, type of substrata and other characteristics to certain of the micro-cell stations. None of the comparator stations was affected by mine waste drainage. They were, however, affected by other influences to the same degree as comparable micro-cell stations.

Station 16 (208 Sampling site P-07; Little Saline Creek, T11S, R5E, between Sections 4 and 9, north of McCormack at county road bridge) was a series of rock riffle segments alternating with rock and sand bottomed pools. The station was well shaded. Flow volume averaged 0.2 cfs. Leaf litter, sticks, and rooted vegetation were in the stream bed. This stretch afforded a varied range of habitats leaning toward cool adapted species and compared well with the natural conditions one would expect in the Eagle Creek watershed.

Station 17 (208 Sampling site ATHW-04; South Fork of the Saline River, T10S, R3E, above the Route 166 bridge in Section 3) was established just above a bend in the stream where it flowed out of a ponded area through a wide channel over shale and limestone rocks. The channel included a wide band of slow moving water in an area of rooted vegetation and a narrower, very fast moving portion with velocities exceeding 3 fps. Flow volume averaged between 9 and 10 cfs. The ponded segment was lined with rocks and logs. This station presented a wide variety of habitats both in terms of water velocities and substrata types. It was chosen as a background station with low acid-buffering capacity, a condition which is common in the Saline drainage basin. This station should be comparable to the lower reaches of Bankston Fork.

Station 18 (208 Sampling site NC-08; Beaucoup Creek, T4S, R2W, 75 feet

upstream from county road bridge in Section 19)included a sand and humus-silt bottomed ponded area and a riffle segment flowing over sticks and logs. Flow volume at this station averaged about 5 cfs. This stream is subject to large, quick increases in discharge during flash flood conditions. There was a great amount of wood and leaf litter in the stream bed. It was well shaded. The sand and silt bottom and logs, twigs and leaf litter together with rooted vegetation afforded a variety of habitats for macroinvertebrates. This stream was chosen for its similarity in natural physical features to Panther Creek.

FIELD METHODS

The 208 micro-cell macroinvertebrate collection stations and three comparator stations were covered in three collecting circuits. Collections began May 30 and were concluded in late July 1977. Hence, collections were carried out in late spring, early summer, and mid-summer. Trips were planned in such a way that all of the stations in a given drainage basin were visited on the same day. Comparator sites were visited as near as possible to the day collections occurred at the corresponding micro-cell stations.

On-site procedures were in two phases: the observation and measure of physical factors and the collection of specimens. The physical factors included pH, water temperature, stream width and depth, water velocity, dissolved oxygen content, and the noting of stream bed features. These measurements and observations were written on a field report form along with the date of last rainfall, and the time span, location and methods of collection.

Temperature and pH were measured directly in the stream. A mercury thermometer was used to obtain water temperature. An electronic pH meter calibrated to pH 4 and pH 7 was used to measure hydrogen ion concentration. In some cases, these measurements were made in a jar of water freshly drawn from the stream.

Stream width and depth were taken where the stream bed was most even and obstructions at a minimum. A graduated steel tape was used for this purpose. Stream velocity was measured in the same stretch of stream (usually just above or below a riffle area) by timing the flow of a charge of rhodamine-B dye solution over a measured course of five or ten feet with a stop-watch. The dye solution was prepared in a squeezable plastic dishwashing detergent bottle with a pull-open top. The bottle made a handy dispenser for the discharge of the dye solution into the stream.

The dye solution was injected upstream of the measured stretch of stream at the cross-sectional point of apparent maximum flow velocity. In most cases, three measurements were averaged and recorded as the velocity. Flow volume per second was estimated by the calculation depth x width/2 x velocity.

Preceding page blank

Dissolved oxygen was measured at each station on the third or final circuit of the stations. Measurements were made using the Hach OX-2P field oxygen test kit. This kit uses a 60 ml water sample taken directly from the stream and processed in the field in a modification of the Winkler titration method. Samples were taken from as far below the surface as possible in shallow waters and in slower reaches of the stream where any existing oxygen demand would not be wiped out by water turbulance saturation effect.

Four basic collecting methods were used to obtain specimens of macroinvertebrates from the stream stations. They were: handpicking from rocks, wood, leaves, and vegetation from the stream with a small forceps, scooping and sieving of sediments, the "kick method" and the use of artificial substrates.

Handpicking was carried out in such a way that all available types of substrata were randomly sampled. An effort was made to collect numbers of individuals that would reflect the observed relative numbers of each species found on each type of substrate. Where numbers were limited, all specimens found on each handpicked example of substrate were collected. Each specimen was dropped into a jar of 95% ethanol as it was collected.

Sediment was scooped with a small tea sieve and shaken through the screen to collect any animals present in the sample. Where soft substrata were plentiful, sieve boxes measuring 38 x 32 centimeters were used to separate silt or sand from specimens. Screen with a mesh of approximately 50 openings per square centimeter was used on these sieve boxes. Animals and detritus collected on the screen were washed into a pan with the sieve box inverted over it or picked from the screen surface with a forceps. An effort was made to randomly sample the sediments according to type and location in stream.

To carry out the kick method, an aquatic net was placed downstream from the collector in relatively fast water and held in position by hand while the substrata several feet upstream from the net were stirred vigorously by foot. This method was used in the standardized manner suggested by Egglishaw and Morgan (1965). The kick method was used more extensively in fast waters. This avoided loss of specimens in the current when rocks were picked up. The net was used alone in areas where water flowed through vegetation.

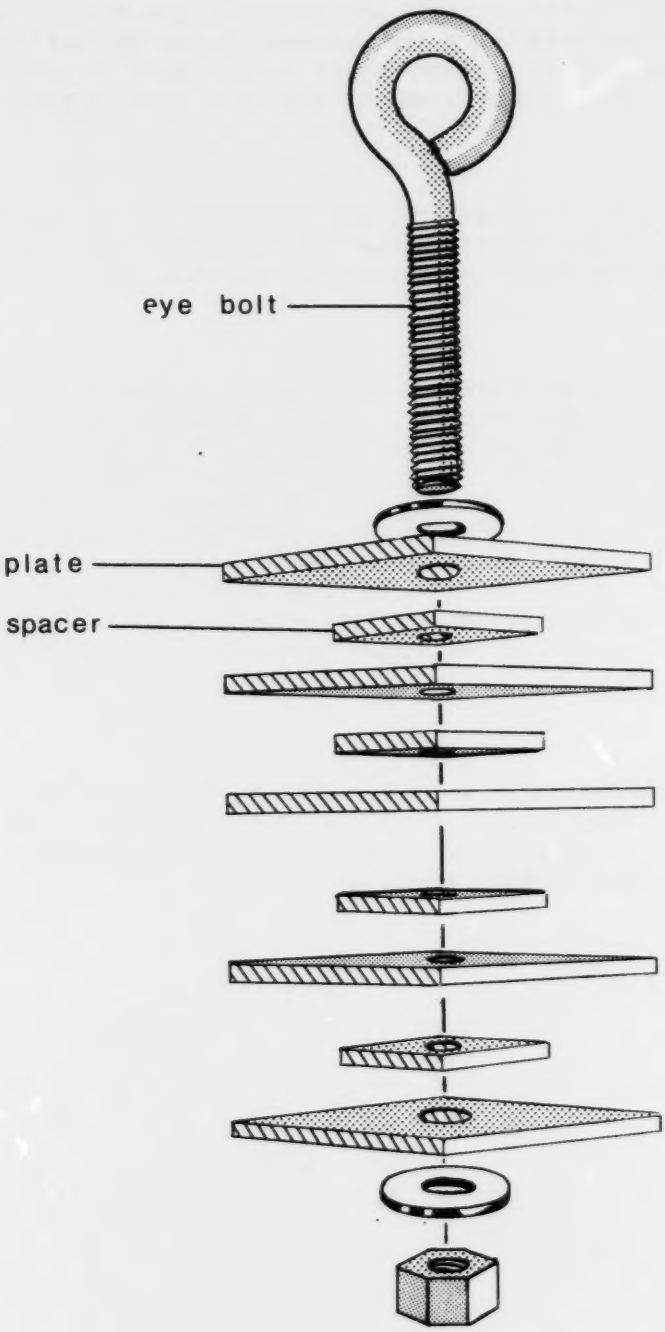
The time devoted to each sampling method varied according to the nature of the stream bed and flow characteristics at each station. Overall time was limited by the law of diminishing returns (Hite and King, 1977). Collection continued until approximately ten minutes had passed since a specimen representing a new taxonomic group was collected. This system was disregarded at stations where no specimens or very few specimens were found. Much longer spans of time were used in such cases.

In all of these collecting methods, the objective was to sample all available substrata and to obtain specimen numbers of each species representative of the relative population size observed in the stream.

Artificial substrates were prepared by assembling four or five tempered masonite hardboard plates measuring 10 x 10 cm. on an eye bolt. One quarter inch thick hardboard was used with spaces of equal thickness separating them (see Figure 2). These devices were attached by wire or plastic rope to stakes or rocks in slow and fast portions of the stream. They were placed in early June and were collected and taken apart in mid to late July. Colonizing animals were removed and placed in jars of 95% ethanol. Many of the artificial substrates were filled with silt and uninhabited when collected, but some bore species not collected by the other methods. Some of the substrates were lost to vandalism or flash flood waters.

All collected specimens were stored in baby food jars partly filled with 95% ethanol until they were examined for identification. Each jar was labeled with collection date, station identification, substrata type, and collection method at the collection site.

FIGURE 2
An Artificial Substrate
(exploded view)



LABORATORY METHODS

Chironomids and other difficult to classify specimens were mounted and cleared in euparal vert mounting medium. The generic key to aquatic insects edited by Usinger (1974) and the keys of Roback (1957) were used to classify the mounted chironomidae = (tendipedidae).

The Frison (1935) key to Illinois Plecoptera was used to classify stoneflies to species. Mayflies (Ephemeroptera) were identified from the key of Burks (1953) and caddisflies (Trichoptera) from the works of Ross (1944).

The aquatic coleoptera and other insect groups were identified to genus from Usinger (1974) and Pennak (1953). The Odonata (dragonflies and damselflies) were checked against the key of Beatty (1967). Works of Beatty (1974 and 1975) were also used to check identification of isopods and to identify the triclad flatworms. Other crustaceans and the mollusks (clams and snails), sponges, byrozoans and annelids (worms and leeches) were identified from the keys of Pennak (1953).

Whenever possible the specimens were classified to species and listed with the binomial species name (see Appendix III). In most cases only one species of a given genus was found at a given station. This means that identifications to genus were most often sufficient for developing species diversity data. Where the full species name (binomial) could not be determined, but specimens differed in taxonomically significant ways, they were identified as species A (sp. A) or species B (sp. B) of the genus. When significantly different specimens could not be classified below family as with the staphylinidae, the same distinction was used. This approach allows accuracy in calculation of mean species diversity even when working with groups for which species classification is difficult or in doubt or when keys to species are unavailable.

As specimens were identified, their names were recorded by station number on separate tally sheets for each collecting circuit. When the tally of specimen numbers for each species at each station was complete, the information was combined into the linear species distribution table found in Appendix III.

SPECIES DIVERSITY CALCULATION

The formula and table of functions used for calculation of mean species diversity were taken from the U.S. E.P.A. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluent (Weber, 1973). The formula used was expressed as $\bar{d}=c/N$ ($N \log_{10} N - \Sigma n_i \log_{10} n_i$) where c = the constant 3.321928 (converting base 10 log to base 2); N = the total number of individuals collected and n_i = the total number of individuals in the i^{th} species.

To obtain the summation of $n_i \log_{10} n_i$, the number of each species represented in the collection was listed and its $n \log_{10} n$ value (from the published table of functions (Weber, 1973) placed after it in a corresponding list. Both columns were then added yielding "N" from the left column and "$\Sigma n_i \log_{10} n_i$" from the right column.

The mean diversity index number obtained by use of these calculations reflects both the richness of species and the distribution of individuals among the species. The $\bar{d}$ value may range from 0 (1 species represented) to 3.321928 log N. This means that if N = 100, mean diversity could range from 0 to 6.64. This range, however, is artificial and has no biological meaning of itself.

For the purposes of this study, the mean species diversities of the various collecting stations with and without mine drainage influence were compared to determine what values would be considered an indicator of good, degraded or poor macroinvertebrates habitat conditions.

Preceding page blank

RESULTS AND DISCUSSION

Physical Parameters

Measurements of selected physical parameters were made at the time of macroinvertebrate collections to aid in delineating the physical characteristics of the stream at each station (Table 1). Dissolved oxygen measurements were made when water temperatures were above the average, hence results were probably lower than would have occurred at the given temperatures.

Specimen Yield

The number of specimens collected ranged from 1 at station 9 on Little Crab Orchard Creek, to 382 at station 17, a comparator station on the south fork of the Saline River. These specimens included 173 species representing 26 orders of which 9 were insects (Appendix III).

Of the insects, Diptera and especially the Chironomidae were best represented. The chironomid species Chironomus anthracinus and the hemipterans Microvelia and Trichocorixa were present at the two stations with the least species represented. Trichocorixa sp. was the only species at station 9 on Little Crab Orchard Creek. Chironomus anthracinus and Microvelia sp. were the only species found at station 12 on Sycamore Creek.

The yield of specimens per man-hour of collecting time (Table 2) is indicative of the relative difficulty or ease with which specimens could be found. It has implications for the relative population densities at the various stations. Activities performed at some stations were limited or not necessary at others, hence the time results given are only useful for comparison within fairly wide ranges of difference.

Intolerant and Tolerant Species

An analysis of data in Appendix III revealed three taxa which showed a

Preceding page blank

Table 1
PHYSICAL CHARACTERISTICS OF WATER AT COLLECTING STATIONS

Station	Water Velocity (Ft./Second)	Flow Volume ($Ft.^3$/Second)	Av. pH	Av. Temp. (Fahrenheit)	Dissolved Oxygen*** (Parts/Million)
1	0.6 fps	0.02	6.6	69.3	7.0
2	1.0 fps	2.10	6.75	70.7	7.0
3	2.3 fps	17.77	6.0	74.6	6.0
4	1.9 fps	2.81	6.0	75.3	5.0
5	2.6 fps	3.40	7.0	82.7	8.0
6	1.0 fps	4.60	6.4	77.3	6.0
7	0.5 fps	0.01	6.3	73.3	NA
8	0.6 fps	0.01*	6.6	76.7	6.0
9	0.5 fps	0.03*	3.2	69.0	0.5
10	0.0 fps	0.00*	4.65**	83.0	3.0
11	0.5 fps	0.09	6.6	72.3	7.0
12	1.0 fps	0.16	2.47	73.3	6.5
13	0.5 fps	0.01	6.35	86.5	NA
14	0.9 fps	0.57	6.6	79.5	6.0
15	1.5 fps	5.08	6.0	77.0	9.0
16	0.7 fps	0.20	6.9	72.7	6.0
17	2.9 fps	9.62	6.35	76.7	6.0
18	1.7 fps	5.11	6.85	77.3	5.0

* Intermittent: flow averaged against 0 for no flow collecting dates.

** Averaged between two pools used for collections. These pools differed from each other by as much as 1.5.

*** Dissolved Oxygen values are not averages. These readings were taken only once (see text).

This Table was prepared from data gathered by Greater Egypt Regional Planning and Development Commission Staff.

Table 2
SPECIMEN NUMBERS PER MAN-HOUR COLLECTION TIME

Station	Stream	Collection Time (Man-Hours)	Specimens/Time
1	Eagle Creek	3.75	33.1
2	Eagle Creek	3.17	22.1
3	Eagle Creek	2.58	116.7
4	Bankston Fork	2.67	7.5
5	Bankston Fork	3.42	73.1
6	Bankston Fork	2.75	23.3
7	Brushy Fork	1.75	49.1
8	Brushy Fork	2.50	35.2
9	Little Crab Orchard	0.75	1.3
10	Little Crab Orchard	1.34	8.2
11	Sycamore Creek	3.16	64.2
12	Sycamore Creek	1.67	87.4
13	Panther Creek	0.83	30.1
14	Panther Creek	2.42	32.6
15	Panther Creek	3.16	17.4
16	Little Saline Creek	3.46	42.2
17	South Fork, Saline River	3.83	99.7
18	Beaucoup Creek	2.75	76.7

This Table was prepared from data gathered by Greater Egypt Regional Planning and Development Commission Staff.

relative intolerance for the kinds of water quality degradation associated with acid mine waste drainage. They include Stenonema of the Ephemeroptera, Pentaneura of the Chironomidae, and the isopod species Asellus Intermedius (Plate 1). All of these taxa were found at each of the comparator stations and with two exceptions they were all found in each of the watersheds (Table 3). However, they were absent from the most affected stations (Table 4).

The intolerant, facultative, tolerant classification system was designed to fit investigations of organic pollution conditions. Since this study focused on mine waste drainage, the terms tolerant and intolerant refer specifically to an apparent tolerance or intolerance of levels of acid mine waste pollution sufficient to cause mean species diversity to drop significantly lower than 3.0

Several species appeared in the water of certain badly polluted stations in small numbers. This included the five specimen of Microvelia collected at Station 12 and the one specimen of Trichocorixa collected at station 9. One tolerant species (Chironomus anthracinus) appeared at two mine waste- polluted stations (stations 10 and 12) in relatively large numbers (Plate 2). The presence of Microvelia at station 12 and of Trichocorixa at station 9 cannot be ruled out as a chance occurrence. Both were collected on only one visit to their respective stations. Microvelia is a surface runner and could easily have migrated upstream from the confluence of Sycamore Creek with Drury Creek about 100 feet away. Trichocorixa swims between the surface and submerged objects. The specimen collected at station 9 could have drifted away from a less polluted pool upstream during the heavy rain which fell a few days before this collecting visit.

Chironomus anthracinus, however, was found in greater numbers and on more than one visit at stations 9 and 12. At station 12, both pupae and pupal exuvia were found along with larvae of various instars of C. anthracinus indicating that this species propagates successfully at station 12. Jonasson (1972) reported that the larva of this species lives in a tube of salivary secretions and silt particles and extends itself from the end of the tube to feed. He indicated that in Lake Esrom, in Denmark, the larvae are active sediment feeders, survive at very low dissolved oxygen levels, and are known to ingest oxidized sediments. The ability to live in low oxygen habitats and to feed on sediments that probably contain much iron as oxide and hydroxide, would certainly adapt this species for survival at stations 10 and 12. Roback (1957) reported this species in Pennsylvania streams.

Table 3
DISTRIBUTION OF TAXA SHOWING LOW TOLERANCE
TO MINE WASTE DRAINAGE

	Station	Asellus	Stenonema	Pentaneura
Eagle Creek	1	x	x	x
	2	-	-	x
	3	x	x	x
Bankston Fork	4	-	-	-
	5	x	-	x
	6	-	-	x
Brushy Fork	7	x	x	x
	8	x	x	-
Little Crab Orchard	9	-	-	-
	10	-	-	-
Sycamore Creek	11	x	x	x
	12	-	-	-
Panther Creek	13	x	-	x
	14	x	x	x
	15	-	-	-
Comparator Stations	16	x	x	x
	17	x	x	x
	18	x	x	x

Key: x = species present at this station.
- = species not found at this station.

This table was prepared from data gathered by Greater Egypt Regional Planning and Development Commission staff.

PLATE 1

Taxa Showing Intolerance to Effects of Acid Mine-Waste Drainage

Figure 1 The aquatic isopod Asellus intermedius

Figure 2 Nymph of the heptageniid mayfly genus Stenonema

Figure 3 Larva of the chironomid genus Pentaneura

Figure 1 modified from Pennak (1953)
Figure 2 modified from Roback (1957)
Figure 3 modified from Burks (1953)

PLATE 1

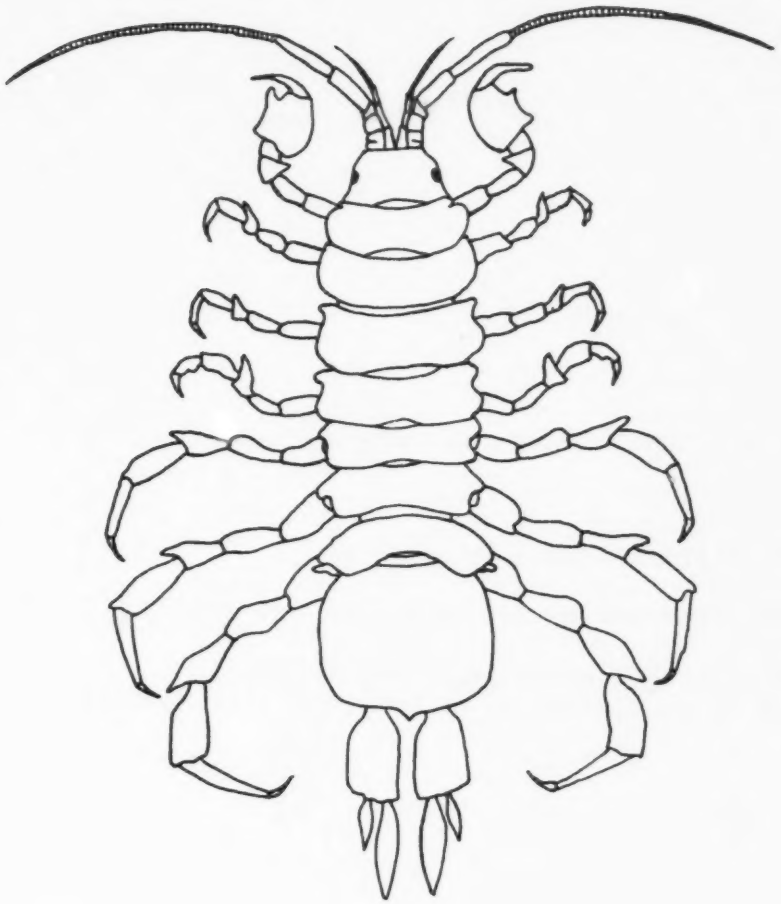


Fig. 1

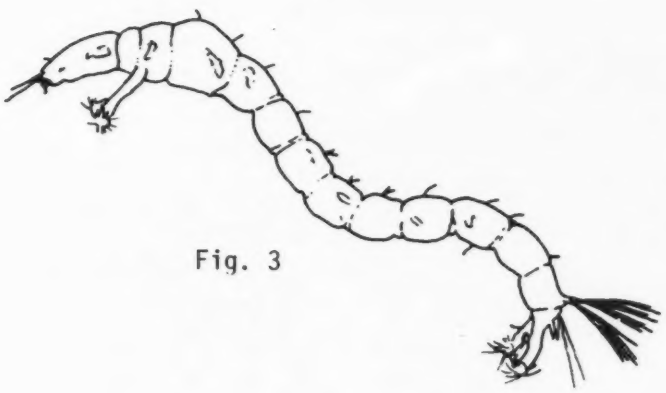


Fig. 3

Fig. 2

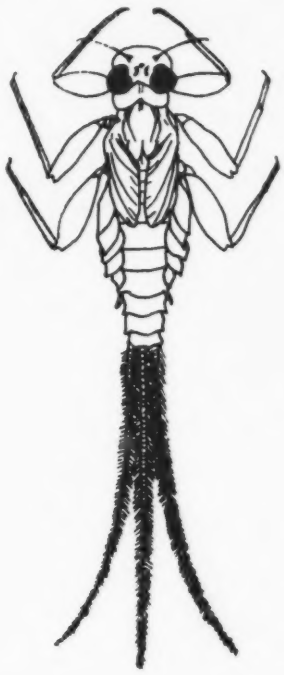


PLATE 2

Taxa Showing Tolerance of Effects of Acid Mine-Waste Drainage

Figure 1 Adult of the hemipteran genus Trichocorixa

Figure 2 Larva of the chironomid species Chironomus anthracinus

Figure 3 Mandible of Chironomus anthracinus (the unpigmented fourth tooth is one distinguishing feature of this species)

Figure 1 redrawn from Usinger (1974)
Figures 2 and 3 drawn from the mounted specimens

PLATE 2

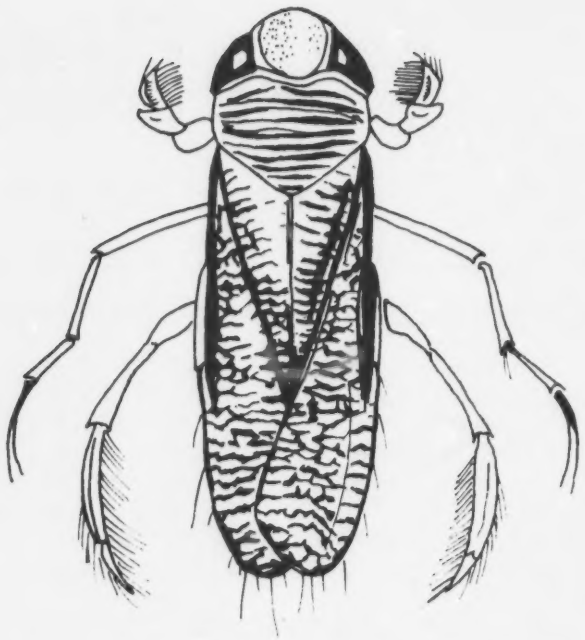


Fig. 1

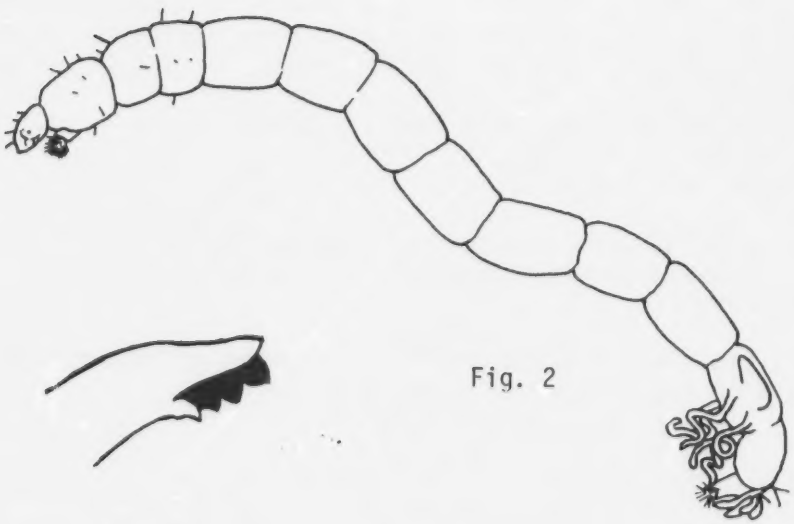


Fig. 2

Fig. 3

Table 4
AVERAGES OF MINE WASTE-RELATED PARAMETERS*
AT STATIONS INHABITED AND NOT INHABITED BY
THREE MINE-WASTE INTOLERANT SPECIES

Station Number	Av. pH	Parameters as Averages for Station Mg/L Sulfate	T.D.S.	Susp. Solids	Alka-linity	Fe.	Mean Species Diversity
Stenonema, Asellus intermedius and Pentaneuna all Present							
1	6.65	33.8	94.2	2.7	13.0	0.13	4.67
3	6.2	416.3	895.0	65.0	10.0	1.88	3.68
7	6.4	182.0	341.0	635.6	48.8	5.60	3.77
11	6.76	168.4	495.5	25.2	198.5	1.45	3.78
14	7.4	757.0	1665.0	233.5	143.3	1.90	3.94
16	6.4	48.3	185.5	3.5	44.3	0.68	4.59
17	6.6	125.0	225.0	31.0	25.5	1.05	2.92
18	6.9	172.8	723.9	48.2	133.9	2.12	4.29
Over-all Average	6.7	238.0	578.1	130.6	77.2	1.85	3.96
Stenonema, Asellus intermedius, and Pentaneura all Absent							
4	6.90	2178.0	3662.0	66.5	295.5	3.67	1.46
9	5.06	264.4	534.4	403.1	- 34.0	20.70	0.00
10	4.49	308.5	528.8	562.5	- 64.0	28.40	2.65
12	4.75	803.0	1133.0	106.9	-195.0	27.93	0.22
15	7.30	870.8	1543.0	503.0	121.0	7.42	1.34
Over-all Average	5.70	884.9	1480.2	328.4	24.1	17.62	1.13

*All chemical data was obtained from the GERP&DC 1977 Micro-cell Rainfall response sampling program. It represents relatively high flow conditions.

This table was prepared from data gathered by Greater Egypt Regional Planning and Development Commission staff.

A related species, Chironomus decorus, is also found at station 10. This species was reported by Roback (1957) as having been found in habitats with pH levels below pH 5.0. C. decorus, however, was not found at any other mine waste-affected stations.

Mean Species Diversity

Mean species diversity reflects not only the number of different species found, but also compares relative numbers of specimens of each species collected. A relatively high mean species diversity was found at Station 14 in spite of a relatively low species number. The opposite situation occurred at Station 17, where species diversity was relatively low in spite of a relatively high number of species represented. These results indicated a fairly even distribution of specimens within the available species at Station 14, while at Station 17 a high number of the specimens collected represented only one species.

The number of different species collected at each station varied from 1 at Station 9 on Little Crab Orchard Creek to 45 at Station 16 on Little Saline Creek (Table 5). Mean species diversity ranged from 0.00 at Station 9 to 4.67 at Station 1 on Eagle Creek upstream from all mining activity (Table 5).

Species diversity was consistently higher in the unaffected segment of a given stream than in the mine waste-affected segments. Some basins exhibited a higher overall diversity than others, but still reflected the pattern of decreasing diversity with increasing mine waste input and increasing diversity when lower segments of the stream showed decreased chemical evidence of mine waste input.

Exceptions to this generalization appear in the instance of measurements from two of the stations. At Station 10 on Little Crab Orchard Creek in Williamson County, a higher than expected mean species diversity was obtained. At this station all chemical data derives from water samples taken during a period of rather constant flow. Macroinvertebrate collections, however, were made during a period when the stream was a series of standing pools which differed from each other in pH by as much as 1.5 (Table 1). Since the major sources of acid mine waste drainage were some distance upstream and little or no flow was occurring, the species collected were probably living in less polluted water than that which was collected for chemical analysis. At Station 17 on the South Fork of the Saline River in Williamson County, mean species diversity

Table 5
MEAN SPECIES DIVERSITY AT MICRO-CELL AND COMPARATOR STATIONS

Stream Name	Station	No. of Species	Mean Diversity
Micro-cell Stations:			
Eagle Creek	1	36	4.67
	2	31	4.60
	3	28	3.68
Bankston Fork	4	5	1.46
	5	28	3.56
	6	14	2.58
Brushy Fork	7	25	3.77
	8	21	3.07
Little Crab Orchard Cr.	9	1	0.00
	10	11	2.65
Sycamore Creek	11	31	3.78
	12	2	0.22
Panther Creek	13	11	2.80
	14	27	3.94
	15	10	1.34
Comparator Stations:			
Little Saline Creek	16	45	4.59
So. Fork, Saline R.	17	36	2.92
Beaucoup Creek	18	39	4.29

This table was prepared from data gathered by Greater Egypt Regional Planning and Development Commission staff.

was unexpectedly low in spite of the fact that this station yielded the highest number of specimens and ranked third among the eighteen stations in number of species. The low mean species diversity figure resulted from the large number of Chuematopsyche sp.a. collected. It is more an expression of the large area of high velocity water and the over-use of kick method sampling at this station than of any aspect of water quality degradation.

For the purposes of this study, a mean species diversity of 4.00 or higher was equated with a relatively undisturbed stable community; 3.00 to 3.99 a possibly stable, but somewhat disturbed community; and below 3.00 a definitely disturbed macroinvertebrate community.

Chemical Parameters and Species Diversity

When mean species diversity data was compared with chemical data from the micro-cell monitoring program and from the six-month 1976 monitoring program there appeared a threshold value for each parameter beyond which mean species diversity figures were consistantly below 3.00. These apparent threshold values were seen for average pH, acidity, iron, and sulfates (Table 6). A rough inverse relationship exists between concentrations of three of these acid mine waste-related parameters and mean species diversity.

pH

Where pH minimums dipped below 5.0 indicating occasional high acidity, mean species diversities of 4.6, 3.07, 0.00, 2.65, 3.78, and 0.22 were recorded. Where average pH was below 5.0, mean species diversities of 0.00, 2.65, and 0.22 were obtained. (Note: the 2.65 is from station 10, where collections were from pools with varying pH values.)

Alkalinity

Mean species diversities of 4.60, 0.00, 2.65, and 0.22 were found at stations that had exhibited negative alkalinity (acidity). An average of 30 mg/l or more acidity existed at three stations. At these, species diversity indexes were 0.00, 2.65, and 0.22.

Table 6
AVERAGE MEAN SPECIES DIVERSITY* AT STATIONS SURPASSING THRESHOLD VALUES** OF FOUR MINE-RELATED PARAMETERS

Parameter	Threshold	Stations	Av. MSD
Av. Acidity	30 mg/l	9-10-12	0.96
Av. Total Fe	6 mg/l	8-9-10-12-13-15	1.68
Av. Sulfate	1400 mg/l	4-6-15	1.79
Av. pH	5.0	10-12	1.44

* Average of MSD values at the indicated stations.

** Average MSD of stations not surpassing any of these "Thresholds" (stations 1-2-3-5-7-11-14-16-17-18) was 3.97.

This table was prepared from data gathered by Greater Egypt Regional Planning and Development Commission staff.

Sulfate

A comparison of 1976 and 1977 data, where both are available for the same station, shows that this ion is likely to concentrate in low flow conditions. At high flow (1977 data) no threshold level seems to exist. Stations that read above 1400 mg/l sulfates in the 1976 and 1977 studies gave mean species diversities of 1.46, 2.58, 0.22, and 1.34. Station 9, which averaged only 264.4 mg/l sulfates in the 1977 high flow study, showed a mean species diversity of 0.00. However, a 1976 reconnaissance sample taken at this station at lower flow showed 800 mg/l sulfate. The low diversity at Station 9 probably relates more to acidity than to sulfate.

Total Iron

With the exception of two stations, iron concentrations above 3 mg/l were associated with mean species diversities below 3.00. Indexes for these stations were 1.46, 2.58, 3.77, 3.07, 0.00, 2.65, 0.22, 2.80, and 1.34. Stations which averaged 20 mg/l or more total iron showed species diversities of 0.00, 2.65, and 0.22. A threshold level for total iron seemed to range between 5 and 20 mg/l. The amount of iron tolerated seemed to depend upon the sulfate concentration (Table 7).

Species Diversity as an Indicator

The macroinvertebrate species examined in this study showed a tendency toward short term tolerance of extremes for the parameters studied. This was demonstrated by a comparison of mean diversity figures from stations which showed a minimum pH below 5.0 to those from stations which showed an average below pH 5.0. Because of this short term tolerance of extremes, determination of thresholds beyond which mean species diversity could be expected to fall below 3.00 was based on averages, not maximums or minimums, of a given parameter. Mean species diversity appeared useful for assessment of general life supportability of mine waste-impacted streams but not for detection of short term or isolated events of water quality degradation.

The wide span of tolerance to suspended solids at some stations indicated that there were some species that were well adapted to short-term heavy sediment loads in these streams. From this it would seem that mean species diversity is less useful in indicating pollution by suspended solids in mine waste-polluted streams than in indicating low

Table 7
COMPARISON OF MEAN SPECIES DIVERSITY,
AVERAGE TOTAL IRON AND AVERAGE SULFATE
(1977 DATA ONLY)

	Station	M.S.D.	Av. Fe.	Av. Sulf.
Eagle Creek	1	4.67	0.13	33.8
	2	4.60	1.92	400.8
	3	3.68	1.88	416.3
Bankston	4	1.46	3.67	2178.0
	5	3.56	0.63	1363.0
	6	2.58	3.20	989.0
Brushy	7	3.77	5.60	182.0
	8	3.07	7.70	220.0
Little Crab Orchard	9	0.00	20.70	264.4
	10	2.65	28.40	308.5
Sycamore	11	3.78	1.45	168.4
	12	0.22	27.93	803.0
Panther	13	2.80	7.10	156.8
	14	3.94	1.90	757.0
	15	1.34	7.42	870.8
Comparators	16	4.59	0.68	48.3
	17	2.92	1.05	125.0
	18	4.29	2.12	172.8

This table was prepared from data gathered by Greater Egypt Regional Planning and Development Commission staff.

average pH conditions and high levels of iron and sulfates.

Tolerance to iron and sulfate levels in mine waste- polluted streams seems, from this study, dependent more on their mean concentration in concert than on high levels of either alone. When the data in Table 6 were analyzed, it was shown that smaller concentrations of total iron were required to result in low mean species diversity at a given station if the sulfate ion was present in abundance than if sulfate was relatively low.

This phenomenon may relate to how these ions (Fe^{++} and SO_4^{--}) were combined in the stream. It is known that ferrous iron will oxidize to its ferric state (Fe^{+3}) in water rapidly if pH is high and dissolved oxygen plentiful, and much more slowly when pH is low and/or dissolved oxygen scarce. As the reaction that produces acidity in water-borne acid mine-waste progresses in highly polluted waters, ferrous sulfate ($Fe\ SO_4$), formed from the oxidation of iron sulfides in water, oxidizes further giving iron hydroxide which precipitates together with ferric sulfate and other metallic salts of low solubility as "yellow boy" (Carrithers and Bulow, 1973). The ferric hydroxide-producing reaction ($4Fe\ SO_4 + O_2 + 10\ H_2O \longrightarrow 4Fe(OH)_3 + 4H_2SO_4$) uses oxygen and creates increasing levels of acidity. If the original burden of pyrites in the stream is great, pH and/or dissolved oxygen could fall low enough to cause accumulation of iron sulfate ($Fe\ SO_4$) in solution. This situation would lead to high amounts of iron and sulfate upon chemical analysis of the water because much of the total iron is still in solution. Death of macroinvertebrates in such an event would most likely result from low pH values and/or lack of dissolved oxygen because of the direct relationship between these parameters and physiological processes. Stations 4, 9, and 12 in this study may represent this type of low pH, low dissolved oxygen environment.

In a well buffered acid mine-waste system, where pH values and dissolved oxygen are relatively high, iron will disappear into the sediments or form a coating on the substrata as the relatively insoluble iron hydroxide ($Fe(OH)_3$). Where this precipitated sediment component or coating exists, mean species diversity tends to be low because the precipitate has altered the habitat and ruled out the presence of many food organisms. Stations 4 and 15 appear to demonstrate this kind of situation.

Further downstream after most of the ferric hydroxide has been precipitated, macroinvertebrate mean species diversity could be unexpectedly high in spite of high sulfates and high total dissolved solids due to the strong buffering capacity of the stream as shown by results at stations 5 and 14. This suggests that the life supportability of mine-waste-affected streams can be enhanced by artifically improving the buffering capacity of the water.

The same possibility is suggested in the conclusions reached by Christensen and Archibald (1976) in their study of the effects of lime neutralization of acid mine drainage on species of diatoms.

Acid Mine-Waste Treatment

Acid drainage treatment plants can accomplish an artificial improvement of buffering capacity via the addition of lime slurry. Through aeration, ferrous iron compounds are oxidized to relatively insoluble ferric iron compounds in the treatment process. The ferric compounds then tend to settle out of the treated water.

Updegraff and Sykora (1976) studied the reaction of coho salmon to this type of treatment and found that lime-neutralized iron hydroxide suspensions having as little as 4.25 mg/l iron caused avoidance behavior. Fresh water mussels were found to repopulate appropriate areas of a naturally recovering stream much less rapidly than insect macroinvertebrate populations (Simmons and Reed, 1973). These findings are generally supported by the results of this study (Appendix III) which show a higher sensitivity to mine-waste parameters by fresh water mussels (clams) than by insect species.

These results suggest that treated acid mine-waste waters and streams in early stages of recovery may show improved macroinvertebrate species diversity before conditions are sufficiently improved to allow fish and shellfish populations.

Conclusions

Mean species diversity values below 3.00 in one of the mine-waste-affected streams of the 208 area would indicate that the life supportability of the stream is seriously threatened by one or more of the following three conditions:

1. Reactions which oxidize pyrites to form metallic salts have robbed waters of dissolved oxygen.

2. Metallic salts originating from mine waste pyrites have yielded acid concentrations beyond the capacity of the stream to buffer them, thus keeping average pH values below 5.0.

3. Sediments and other substrata potentially available to macroinvertebrates are coated with ferric hydroxide, ferric hydrates, and other compounds of low solubility.

The life supportability of acid mine-waste- affected streams in the 208 area can be evaluated using mean species diversity values derived from collections of macroinvertebrates during high production months. The absence of certain intolerant species from macroinvertebrate collections can serve as an indicator of high levels of mine-waste- related parameters, but no species can act as an indicator of any given parameter by its presence or absence.

Results obtained in this study suggest that mean species diversity in mine-waste affected streams can be enhanced by:

1. Increasing the buffering capacity of the stream and reducing the total iron content of the water via precipitation of ferric hydroxide.

2. Removal of pyritic material from contact with surface water and/or oxygen supply in the watershed.

The first of these alternatives can be accomplished by lime slurry, aeration, and settling treatment. Such treatment must be continuous and requires construction and upkeep of treatment facilities. When such treatment is carried out there is still no assurance that a normal biota including fish and shellfish can become established as a result.

Removal of the source of pyritic material from the watershed or from contact with oxygen and surface waters would seem the better approach because long-term maintenance of facilities would be unnecessary and the ensuing period of recovery could reasonably be expected to end in the establishment of a normal regional biota.

LITERATURE CITED

Beatty, Joseph A., 1974. "Key to the terrestrial and freshwater isopods of Illinois." Department of Zoology, Southern Illinois University: Carbondale.

Beatty, Joseph A., 1975. "Key to the land and freshwater triclad turbellaria of North America." Department of Zoology, Southern Illinois University: Carbondale.

Beatty, Joseph A., 1976. "Key to the nymphs of odanata occurring or possibly occurring in Illinois." Department of Zoology, Southern Illinois University: Carbondale.

Burks, B. O., 1953. "The mayflies or ephemeroptera of Illinois." Natural History Survey Bulletin, Vol. 26 (#1).

Carrithers, Ralph B. and Bulow, Frank J., 1973. "An ecological survey of the west fork of the Obey River, Tennessee with emphasis on the effects of acid mine drainage." Journal of the Tennessee Academy of Science, 48 (2): 65-72.

Christensen, C. L., and Archibald, P. A., 1976. "Effectiveness of lime neutralization in stream recovery from acid-mine pollution as indicated by species of diatoms." Phytologia, 34 (1): 5-17.

Egglishaw, H. J., and Morgan, N. C., 1965. "A survey of the bottom fauna of streams in the Scottish Highlands part II. The relationship of the fauna to the chemical and geological conditions." Hydrobiologie.

Frison, Theodore H., 1935. "The stoneflies or plecoptera of Illinois." Illinois Natural History Survey Bulletin, Vol. 20.

Herricks, Edwin E., and Shanholtz, Vernon O., 1976. "Predicting the environmental impact of mine waste drainage on stream biology." Transactions of the ASAE, Vol. 19.

Hines, H. B. N., 1972. The Ecology of Running Waters, University of Toronto Press.

Hite, Robert L., and King, Marvin, 1977. "Biological investigation of the Crab Orchard Creek Basin." Illinois Environmental Protection Agency, State of Illinois.

Jonasson, Petur M., 1972. "Ecology and production of the profundal benthos in Lake Esrom." Oikos Supplementum 14, Munksgarrd, Copenhagen.

Preceding page blank

Parsons, John David, 1968. "The effects of acid strip-mine effluents on the ecology of a stream." Archiv. F. Hydrobiologie, Vol. 65.

Parsons, John David, 1974. "Effects of acid mine wastes on aquatic ecosystem." Department of Botany, Southern Illinois University: Carbondale.

Pennak, Robert W. 1953. Freshwater Invertebrates of the United States. Ronald Press Co.: New York.

Roback, Selwyn S., 1957. "The immature tendipedids of the Philadelphia area." Monographs of the Academy of Natural Sciences of Philadelphia, No. 9.

Ross, Herbert H., 1944. "The caddisflies or trichoptera of Illinois." Illinois Natural History Survey Bulletin, Vol. 23.

Rosso, Allen W., 1975. "The ecology of the South Fork of the Saline River as affected by surface mine wastes." Doctoral dissertation, Department of Zoology, Southern Illinois University: Carbondale.

Simmons, George M., Jr., and Reed, James R., 1973. "Mussels as indicators of biological recovery zone." Water Pollution Control Federation Journal, 45 (12): 2480-2492.

Updegraff, Karl F. and Sykora, Jan L., 1976. "Avoidance of lime-neutralized iron hydroxide solutions by coho salmon in the laboratory." Environmental Science Technology, 10 (1): 51-54.

Usinger, Robert L., ed., 1974. "Aquatic insects of California with keys to North American Genera and California species." University of California Press: Berkeley and Los Angeles.

Weber, Cornelius I., ed., 1973. "Biological field and laboratory methods for meauring the quality of surface waters and effluents." EPA-670/4-73-001, National Environmental Research Center: Cincinnati.

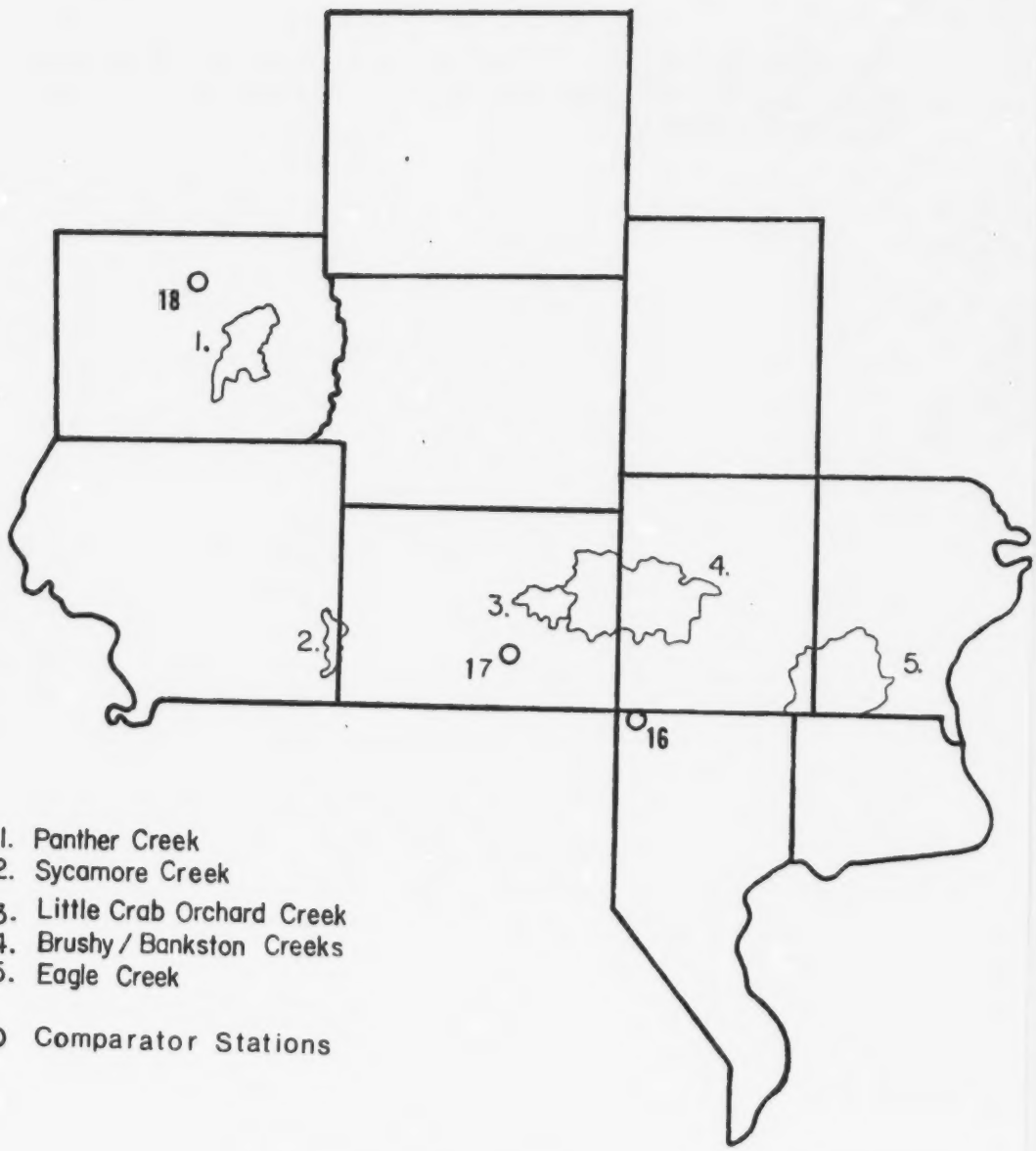
Wilhm, Jerry L., and Dorris, Troy C., 1968. "Biological parameters for water quality criteria." Bioscience, Vol. 18 (#6).

Young, Willard C.; Kent, David H; and Whiteside, Bobby B., 1976. "The influence of a deep storage reservoir on the species diversity of benthic macroinvertebrate communities of the Guadalupe River, Texas." The Texas Journal of Science, Vol. 27 (#1).

APPENDIX I

The micro-cell watersheds showing the location of 208 micro-cell sampling stations and comparator stations at which macroinvertebrate animals were collected.

MICRO-CELL SAMPLING WATERSHEDS



1. Panther Creek
2. Sycamore Creek
3. Little Crab Orchard Creek
4. Brushy / Bankston Creeks
5. Eagle Creek

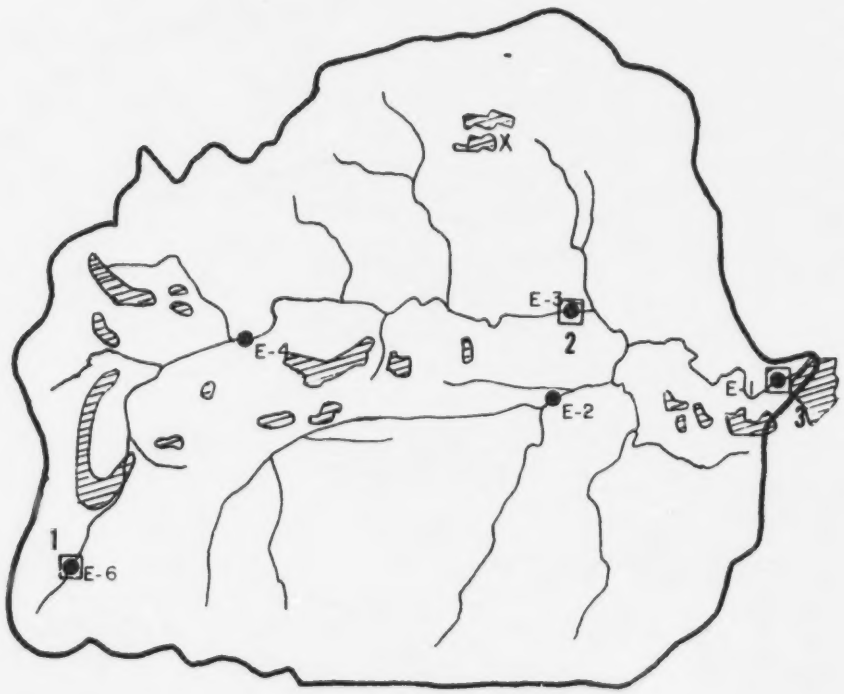
O Comparator Stations

-N-

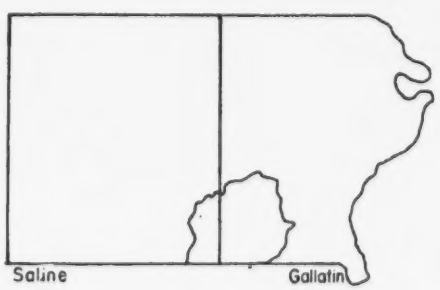
GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

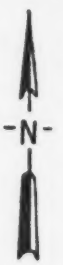
The preparation of this map was financially aided through Federal Grant No. P005225 01 through the U.S. Environmental Protection Agency under the Water Pollution Control Act Amendments of

EAGLE CREEK MICRO-CELL



- COLLECTING STATIONS
- MICRO-CELL SAMPLING STATIONS
- X MINE REFUSE
- SURFACE MINE

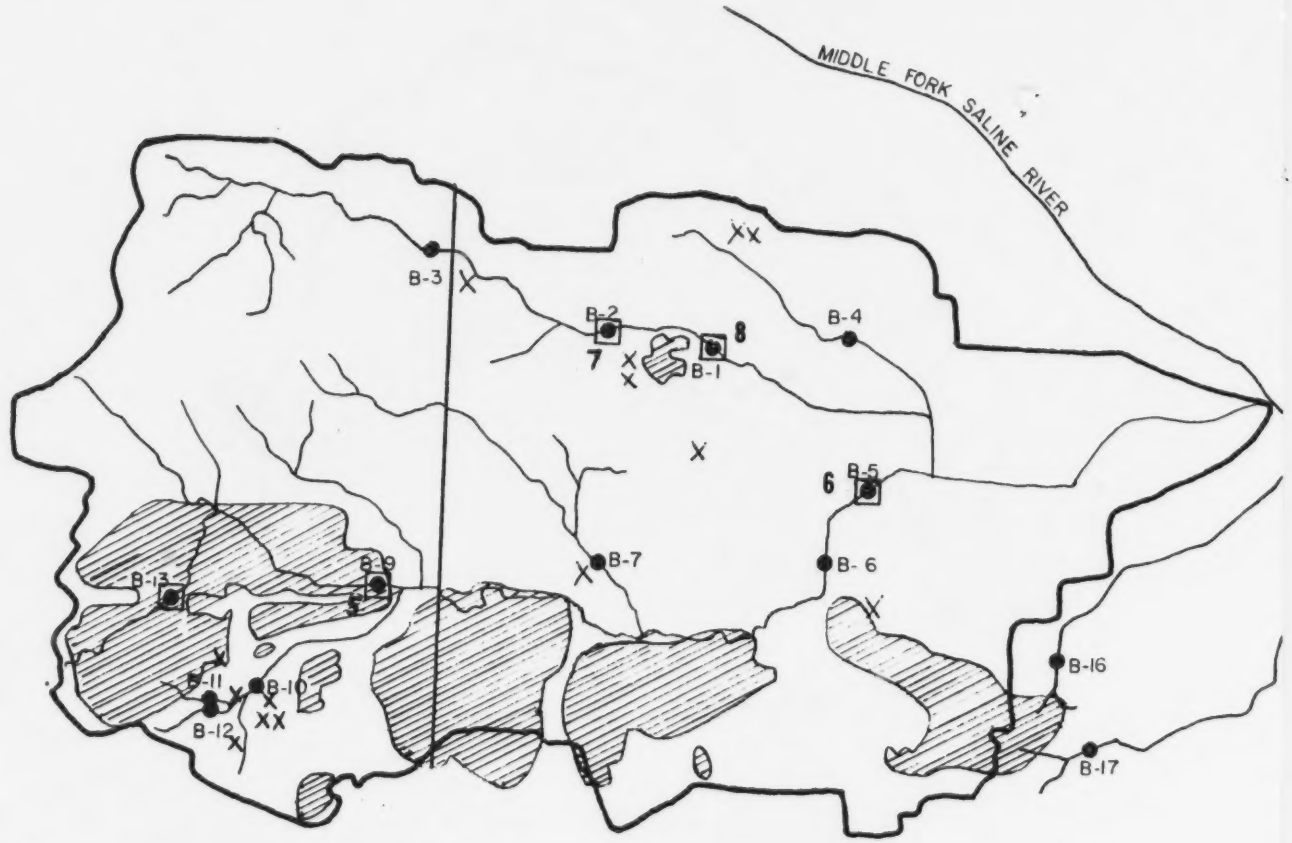




GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

The preparation of this map was financially aided through Federal Grant No. P005225 01 through the U.S. Environmental Protection Agency under the Water Pollution Control Act Amendments of 1972.

BRUSHY/BANKSTON CREEK MICRO-CELL

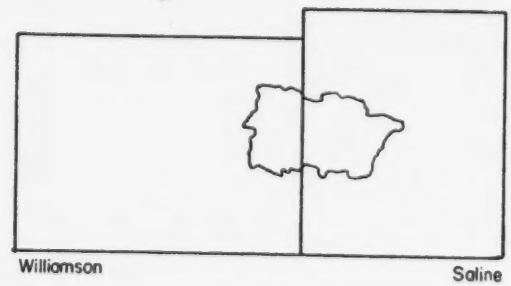


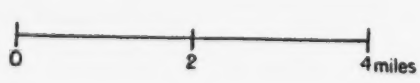
COLLECTING STATIONS

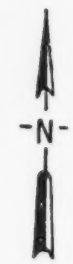
MICRO-CELL SAMPLING STATIONS

X MINE REFUSE

SURFACE MINE



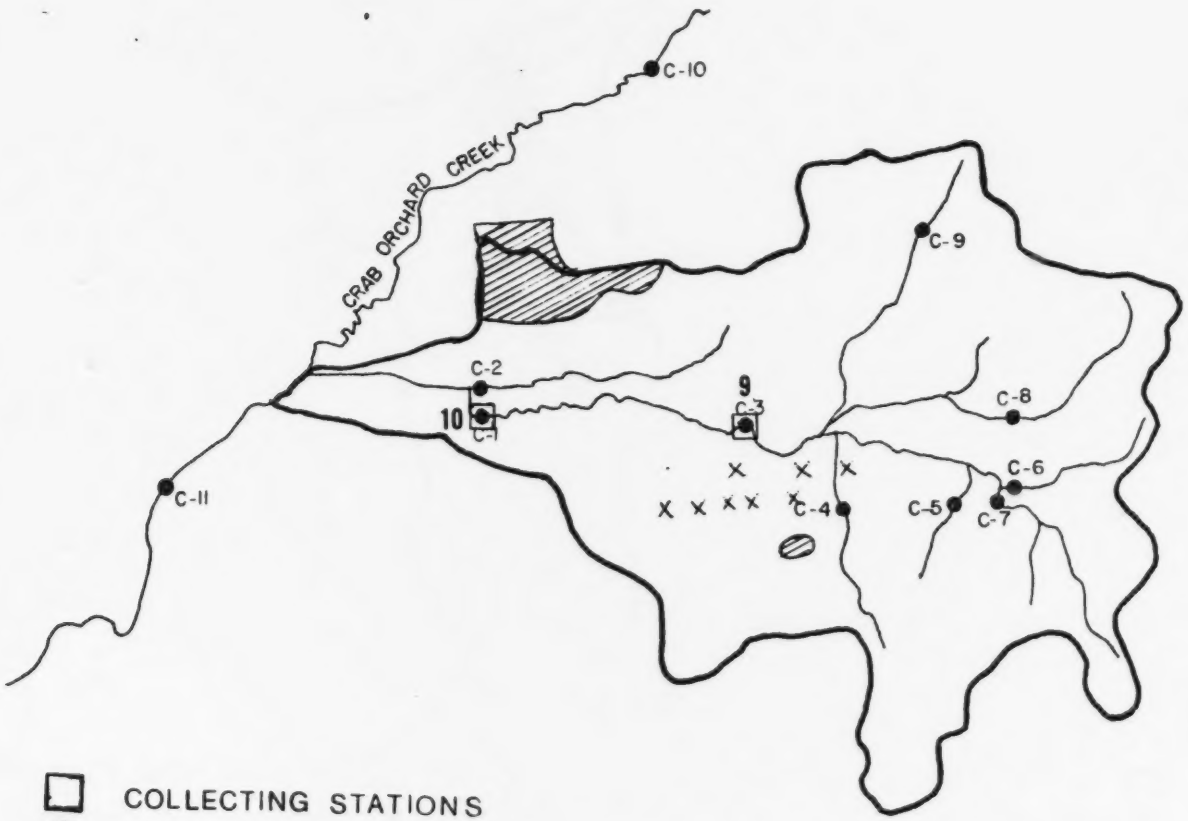




GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

The preparation of this map was financially aided through Federal Grant No P005225 01 through th U.S. Environmental Protect Agency under the Water Poll Control Act Amendments of

LITTLE CRAB ORCHARD CREEK MICRO-CELL



COLLECTING STATIONS

MICRO-CELL SAMPLING STATIONS

X MINE REFUSE

SURFACE MINE

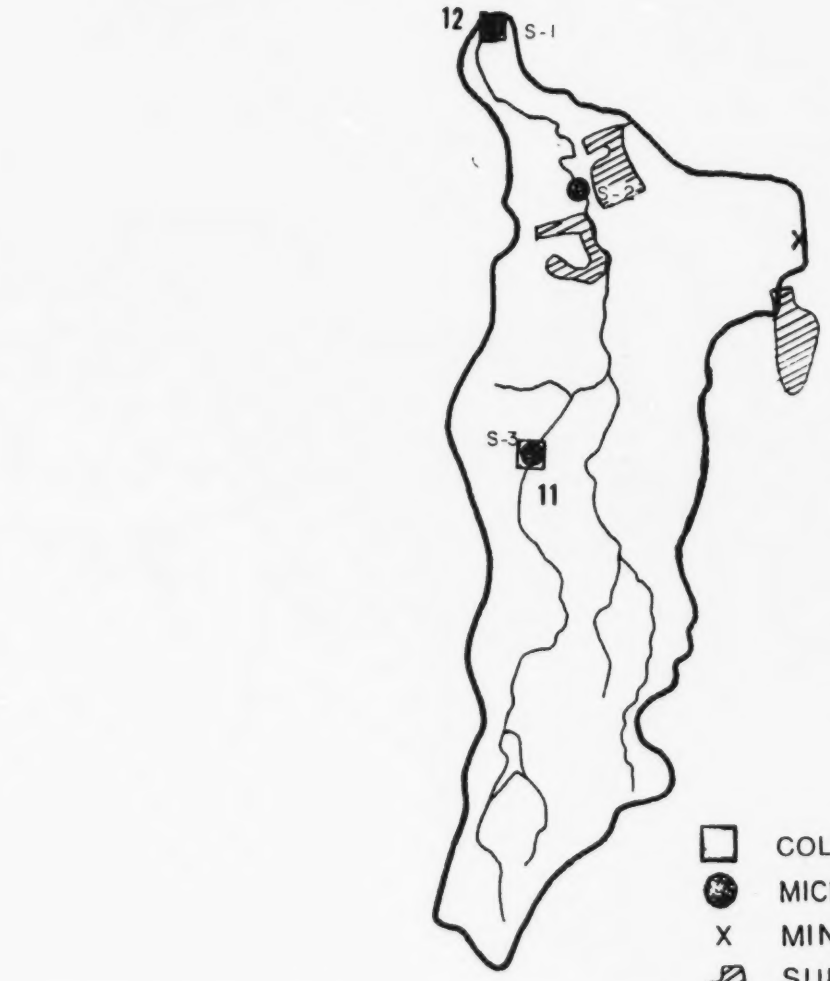
-N-

0 1 2miles

GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

The preparation of this map was financially aided through Federal Grant No P005225 01 through the U.S Environmental Protection Agency under the Water Pollution Control Act Amendments of 1972

SYCAMORE CREEK MICRO-CELL

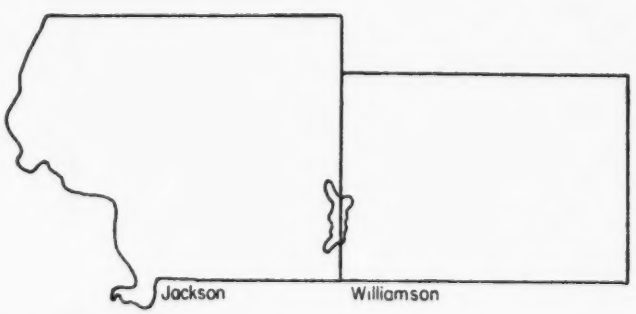


COLLECTING STATIONS

MICRO-CELL SAMPLING STATI

X MINE REFUSE

SURFACE MINE



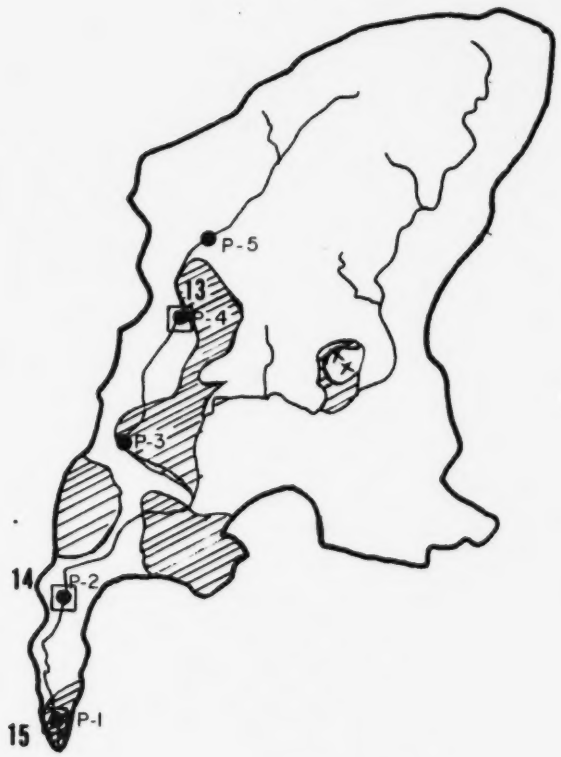
-N-

0 1 2miles

GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

The preparation of this map was financially aided through Federal Grant No. P005225 01 through th U.S. Environmental Protect Agency under the Water Pol Control Act Amendments of

PANTHER CREEK MICRO-CELL

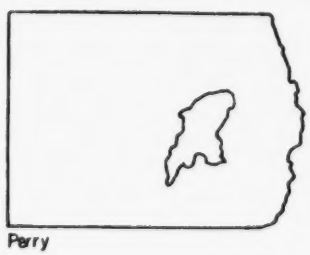


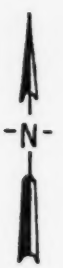
COLLECTING STATIONS

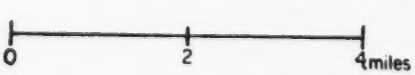
MICRO-CELL SAMPLING STATIONS

X MINE REFUSE

SURFACE MINE







GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION

The preparation of this map was financially aided through Federal Grant No. P005225 01 through the U.S. Environmental Protection Agency under the Water Pollution Control Act Amendments of 1972

APPENDIX II

The following chart provides a chemical profile of the micro-cell stations (1-15) and the comparator stations (16, 17, & 18) used as collection stations in this study. It should be noted that the data labeled "1977" is rainfall response data and reflects the effects of direct run-off from the basin area tributary to the station during a rainfall event. Data labeled "1976" is data collected during the 6-month sampling project of that year and reflects a variety of run-off situations in a relatively dry year.

All amounts are given in mg/l. "Max." = maximum amount, "Min." = minimum amount and "Av." = average for all samples tested during the indicated sampling program. Designations for the same sampling site differ between the 1977 and 1976 sampling programs.

Preceding page blank

CHEMICAL PROFILE OF STATIONS

Sta.	208 Site		Ph	Sulf.	T.D.S.	S.S.	Alk.	Fe
1	E-6	Max.	7.2	45	130	8	+32	0.2
	1977	Min.	6.3	20	55	0	- 2	0
		Av.	6.65	33.8	94.2	2.7	+13	0.13
2	E-3	Max.	6.25	675	1000	170	-12	3.2
	1977	Min.	5.5	130	210	6	-30	0.02
		Av.	6.05	400.8	610	67.3	-20.5	1.92
	ATE-05	Max.	7.0	2500	3900	25	+56	1.8
	1976	Min.	4.5	150	290	2	-190	0.07
		Av.	6.0	1069.3	1694	11.2	- 9.3	0.44
3	E-1	Max.	6.8	475	1710	85	+24	2.5
	1977	Min.	5.7	325	530	55	- 6	1.4
		Av.	6.2	416.3	895	65	+10	1.88
	ATE-01	Max.	7.7	1600	2170	110	+120	3.3
	1976	Min.	6.0	50	220	1	-16	0
		Av.	6.88	456,2	842	20.2	+60.8	0.83
4	B-13	Max.	7.7	2900	4100	290	+340	17.5
	1977	Min.	5.8	1500	2860	5	+200	0.8
		Av.	6.9	2178	3662	66.5	+295.5	3.67
5	B-9	Max.	8.1	1700	2740	160	+210	1.8
	1977	Min.	5.8	1000	1660	8	+120	0.02
		Av.	7.3	1363	2250	44.5	+164.5	0.63
6	B-5	Max.	8.0	1450	2820	650	+120	7.5
	1977	Min.	5.9	450	770	9	+20	0.8
		Av.	6.9	989	1677	159	+68	3.2
	ATGC-02	Max.	7.7	2400	3670	39	+196	5.9
	1976	Min.	5.0	900	1570	1	-44	0.1
		Av.	6.9	1516	2472	8.7	+111	0.98
7	B-2	Max.	7.4	275	400	2860	+220	21.0
	1977	Min.	5.0	120	235	3	-16	0.15
		Av.	6.4	182	341	635.6	+48.8	5.6
8	B-1	Max.	7.3	350	475	2000	+55	42.5
	1977	Min.	5.4	70	205	8	-30	0.1
		Av.	6.4	220	383.9	464	+26.2	7.7
	ATGCS-10	Max.	8.8	575	1220	1200	+75	30.8
	1976	Min.	3.3	75	260	0	-20	0.1
		Av.	6.7	251	880	84.5	+43.5	2.4

Sta.	208 Sites		Ph	Sulf.	T.D.S.	S.S.	Alk.	Fe
9	C-3	Max.	6.0	550	1000	1340	+30	42.5
	1977	Min.	3.0	100	260	160	-70	5.0
		Av.	5.06	264.4	534.4	403.1	-34.4	20.7
10	C-1	Max.	6.0	525	860	2260	-28	85.0
	1977	Min.	3.0	133	260	18	-160	10.4
		Av.	4.49	308.5	528.8	562.5	-64	28.4
11	S-3	Max.	8.0	300	880	48	+380	2.7
	1977	Min.	4.8	100	325	11	+100	0.15
		Av.	6.76	168.4	495.5	25.2	+198.5	1.45
12	S-1	Max.	6.7	2000	3360	350	-18	65.0
	1977	Min.	2.6	265	500	40	-610	11.5
		Av.	4.75	803	1133	106.9	-195	27.93
	NDJ-01	Max.	5.8	2760	4820	1900	+26	60.0
	1976	Min.	2.45	150	320	0	-1200	2.8
		Av.	3.37	1361	2508	96.1	-445.6	21.89
13	P-4	Max.	7.8	362	710	3040	+220	16.2
	1977	Min.	5.9	50	200	150	-100	3.3
		Av.	6.96	156.8	282.7	823.8	+30.4	7.1
14	P-2	Max.	7.9	1400	2460	660	+210	2.9
	1977	Min.	6.6	275	540	15	+50	0.3
		Av.	7.4	757	1665	233.5	+143.3	1.9
15	P-1	Max.	7.8	1700	2990	2340	+190	28.0
	1977	Min.	6.5	275	600	13	+56	0.7
		Av.	7.3	870.8	1543	503	+121	7.42
	NCP-04	Max.	8.2	2800	4000	100	+290	2.9
	1976	Min.	6.8	525	1410	4	+65	0.20
		Av.	7.6	1870	3449	32.8	+196	0.93
16	P-07	Max.	6.7	100	720	7	+100	2.30
	1976	Min.	5.8	15	108	0	- 6	0.05
		Av.	6.4	48.3	185.5	3.5	44.3	0.68
17	ATHW-04	Max.	7.2	250	490	80	+60	1.8
	1976	Min.	6.0	35	115	2	-16	0.14
		Av.	6.6	125	225	31	+25.5	1.05
18	NC-08	Max.	7.7	450	1820	180	+240	5.6
	1976	Min.	6.2	50	270	5	+28	0.6
		Av.	6.9	172.8	723.9	48.2	+133.9	2.12

APPENDIX III

The following is a linear chart of all species collected in this study of macroinvertebrate species diversity in 15 stations in the 208 micro-cell basins and in three comparator stations (numbers 16, 17 and 18). The station numbers progress downstream for each stream from left to right on the chart. The numbers also correspond to those which identify the stations among the 208 sampling sites on the Micro-cell basin maps in Appendix I.

Preceding page blank

Reproduced from best available copy.

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS													COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM) / FAMILY / SPECIES (OR GENUS)																		
Porifera (Sponges)																		
Spongillidae																		
Spongilla fragilus																9		
Tricladida (flat worms, in part)																		
Planariidae																		
Dugesia Tigrina			1		6						3							
Bryozoa (moss animals)																		
Plumatellidae																		
Plumatella repens					2													2
*Plumatella Sp.A**								1										
Lophopodidae																		
Fredericella sultana																	4	1
Opisthopora (earthworms, in part)																		
Haplotaxidae																		
Haplotaxis		1																
Plesiopora (aquatic earthworms)																		
Tubificidae																		
Tubifex tubifex																		1
Limnodrilus		1	4															3
Branchiura sowerbyi																	3	
Rhyncobdellida (leeches)																		
Glossiphoniidae																		
Helobdella					2													1
Erpobdellida (leeches)																		
Erpobdellidae																		
Dina microstoma																		4

*Sp. A, B, etc. designates a distinct species that could not be further identified with available materials.

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS														COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Cladocera (water fleas)																		
Eurycercinae																		
Eurycercus lamellatus		6																
Copepoda (copepods)																		
Cyclopidae																		
Paracyclops fimbriatus		2																
Ostracoda (clam shrimps)																		
(Specimens not further identified)														3				
Isopoda (sow bugs)																		
Asellidae																		
Asellus intermedius	3		45		15		19	18			22		2	1		4	5	23
Amphipods (side swimmers)																		
Talitridae																		
Hyalella azteca			15				4	4						1				
Decapoda (crayfish and shrimp)																		
Astacidae																		
Orconectes rusticus																		
Orconectes virilis	2	2		1			1	1			2			1	1	6		5
Orconectes immunis	2																	
Orconectes obscurus		2	1															
Cambarus fodiens											2							
Palaemonidae																		
Palaemonetes kadiakensis														2				

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS													COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Hydracarina (water mites)																		
Limnocharidae																		
Limnochares													1					
Colembola (Colembolans)																		
Isotomidae																		
Isotomurus palustris		1				1	2	1								1	1	1
Ephemeroptera (may flies)																		
Caenidae																		
Caenis																		
Baetidae		3	31		5	1		1			3		1	8			1	11
Cloeon simplex		1			1													
Neocloeon alamance											9						6	
Neocloeon Sp.A			1															
Pseudocloeon minutum											1							
Ameletus lineatus											1							
Ameletus ludens	1		1								1						3	
Ephimeridae																		
Hexagenia limbata																2		2
Heptageniidae																		
Stenonema femoratum	5						3									4		
Stenonema heterotarsale								7								1	46	
Stenonema tripunctatum								35			11					3	5	
Stenonema gildersleevei			59								8			1		2	10	4
Stenonema candidum											2							
Stenonema interpunctatum											1					1		
Leptophlebiidae																		
Paraleptophlebia praepedita	1															1		

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS												COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Odonata (dragonflies and damselflies)																		
Agrionidae																		
Agrion					7									1		1	3	
Coenagrionidae																		
Amphiagrion					3			1										
Ischnura				2	1		1									1		2
Argia					3													
Anomalagrion hastatum					3													
Lestes						1								2				
Chromagrion																	2	
Aeschnidae																		
Boyeria						2										1	1	
Basiaeschna janata								1										
Gomphaeschna															1			
Aeschna	1																	
Libellulidae																		
Didymops		1	1															
Macromia						3												
Helocordula								2										
Plecoptera (stone flies)																		
Perlidae																		
Neoperla clymene																1	7	9
Perlesta placida																5		
Perlinella drymo																		
Neophasganophora capitata	4												2					
Acroneuria																1		
Pteronarcidae																		
Pteronarcella		1																

Reproduced from best available copy.

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS														COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup C
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATH-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Hemiptera (water striders, true bugs)																		
Veliidae																		
Microvelia	4	2	2		1		7	4		3	5	5						
Rhagovelia					3													
Gerridae																		
Gerris incognitus			2					1										
Gerris remigis	3				1													
Gerris Sp.A							2				5							1
Trepobates		1	1				1	1		1	4					1		1
Hydrometridae																		
Hydrometra martini							1											
Corixidae																		
Trichocorixa									1									
Dasycorixa																		
Tricorixa																		
Cenocorixa	2									3								1
Notonectidae																		
Notonecta		1																
Megaloptera (alderflies and helgramites)																		
Corydalidae																		
Corydalus cornutus																		
Chauliodes			1												2			
Sialidae																		
Sialis										12				4				
Trichoptera (caddisflies)																		
Hydropsychidae																		
Cheumatopsyche Sp.A	5	3	30	2	73	3	15				58		1	22	44	35	189	61
Cheumatopsyche Sp.B											2							12

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS												COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Trichoptera,																		
Hydropsychidae (continued)																	2	
Hydropsyche																	5	
Arctopsyche														1	1			
Potomyia					15													
Smicridea	5																	
Diplectrona felix						1												
Psychomyiidae														2				
Genus A (Ross)																		1
Polycentropus remotus											1						1	
Polycentropus Sp.A						11												
Neureclipsis																		
Philopotamidae											30							
Chimarra ferria					4										1		1	
Dolophilodes																		
Wormaldia	12	1																
Rhyacophilidae																1		
Rhyacophila lobifera																		
Lepidoptera (moths & butterflies)																		
Nymphalidae																		
Synclita	1																	
Coleoptera (beetles)																		
Elmidae																1		
Simsonia																		
Dubiraphia vittata			2															
Stenelmis Sp.A	6		9		22		1				8			2	1	4	50	8
Stenelmis Sp.B																		2
Narpus																1	2	

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS													COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Coleoptera,																		
Elmidae (continued)																		
Ancyronx																		
Microcylloepus																	3	
Macronychus glabratus	2																	1
Dryopidae																		
Dryops	6							2								2		
Throscinus							1											
Helichus							11											
Pelonomus	1															1		
Dytiscidae																		
Hydroporus																1		
Bidessus							1										1	
Copelatus								2										
Agabetes	2																	
Coptotomis	3															4		
Colymbetes										1						2		
Laccophilus								1										
Gyrinidae																		
Gyrinus					1					1	1					2		
Dineutus		3									9			4	1	1	4	2
Staphalinidae																		
Species A					1		1								1	7		1
Species B																2		
Hydrophilidae																		
Hydrobius	18										1							
Helophorus	1	2																
Crysomelidae																		
Species A																	1	
Heteroceridae																		
Species A	1																	

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS													COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Diptera (crane flies, mosquitos, midges, etc.)																		
Tipulidae																		
Bezatoma																1		
Culicidae																		
Anopheles occidentalis		1																
Species A														1				
Dixidae																		
Dixa	2																	
Simuliidae																		
Simulium			39	14	45										2			
Chironomidae (Tendipedidae)																		
Pentaneura Sp.A	6	5	20		21	31	3				4		2	1		9	1	10
Pentaneura carnea			1													1		
Pentaneura decolorata							1							1				
Chironomus (tendipes) Sp.A	1	1							1								1	1
Chironomus anthracinus									16			141						
Chironomus decorus									2									2
Chironomus riparius		4					2		25									
Limnochironomus modestus					1		4	1										1
Limnochironomus neomodestus		1	7		1			1									1	
Limnochironomus nervosa														4				
Calopsectra Sp.A		4	3										1	1		8	11	3
Calopsectra guerla			2															
Zavrelia		2														1		
Lautenborniella																2		
Glyptotendipes senilis	1	9																
Symbiocladius equitans	2																	
Pseudochironomus							1		7		1							
Harnischia																		

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS													COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	E-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM) / FAMILY / SPECIES (OR GENUS)																		
Diptera,																		
Chironomidae (continued)																		
Tanytarsus divinctus							1											
Tanytarsus obediens			7								2			1				
Tanytarsus nigricans																1		
Polypedilum tritum	2																	
Polypedilum fallax	7	3	8		1		1				1							2
Polypedilum scalaenum			4															
Polypedilum sodens											2							
Polypedilum illinense																		
Cricotopus					3	6											2	
Stenochironomus			2										2	1				
Smittia					3											1		
Anatopynia																		
Tanypus																	5	
Chaoborus		1																2
Cryptochironomus	4																	
Corynoura																	1	
Heleidae (Cerotopogonidae)																		1
Palpomyia	4	1	1							4	1		1					
Stratomyiidae																		
Stratomyia	1																	
Odontomyia	1													2				
Empididae																		
Hermerodromia			2		1	1					1						1	
Antnomyiidae																		
Species A					3													
Limnophor discreta		3																
Ephidridae																		
Species A							1											

Reproduced from
best available copy.

AQUATIC MACROINVERTEBRATES FOUND IN FIVE SOUTHERN ILLINOIS STREAMS BETWEEN MAY 30 AND AUGUST 29, 1977

	MICRO-CELL STATIONS														COMPARATOR STATIONS		
Stream Name:	Eagle Creek			Bankston Fork			Brushy Fork		Little Crab Orchard		Sycamore Creek		Panther Creek			Little Saline	South Fork Saline	Beaucoup Cr.
208 Site Number:	S-6	E-3	E-1	B-13	B-9	B-5	B-2	B-1	C-3	C-1	S-3	S-1	P-4	P-2	P-1	P-07	ATHW-04	NC-08
Station Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORDER (OR PHYLUM)																		
FAMILY																		
SPECIES (OR GENUS)																		
Pulmonata (pulmonate snails)																		
Physidae																		
Physa		1		1	6		1						1	8		3		11
Lymnaeidae																		
Lymnaea	2															1		
Planorbidae																		
Carnifex						1												
Gyraulus							1											
Ancylidae																		
Ferrissia rivularis	1																	5
Rhodacmea																		
Pelecypoda (clams or mussels)																		
Unionidae																		
Anodontoides																		
Anodonta														1				
Sphaeriidae																		5
Sphaerium													11	1		5	1	2
Musculum					1									2		1	1	1
Pisidium																3		